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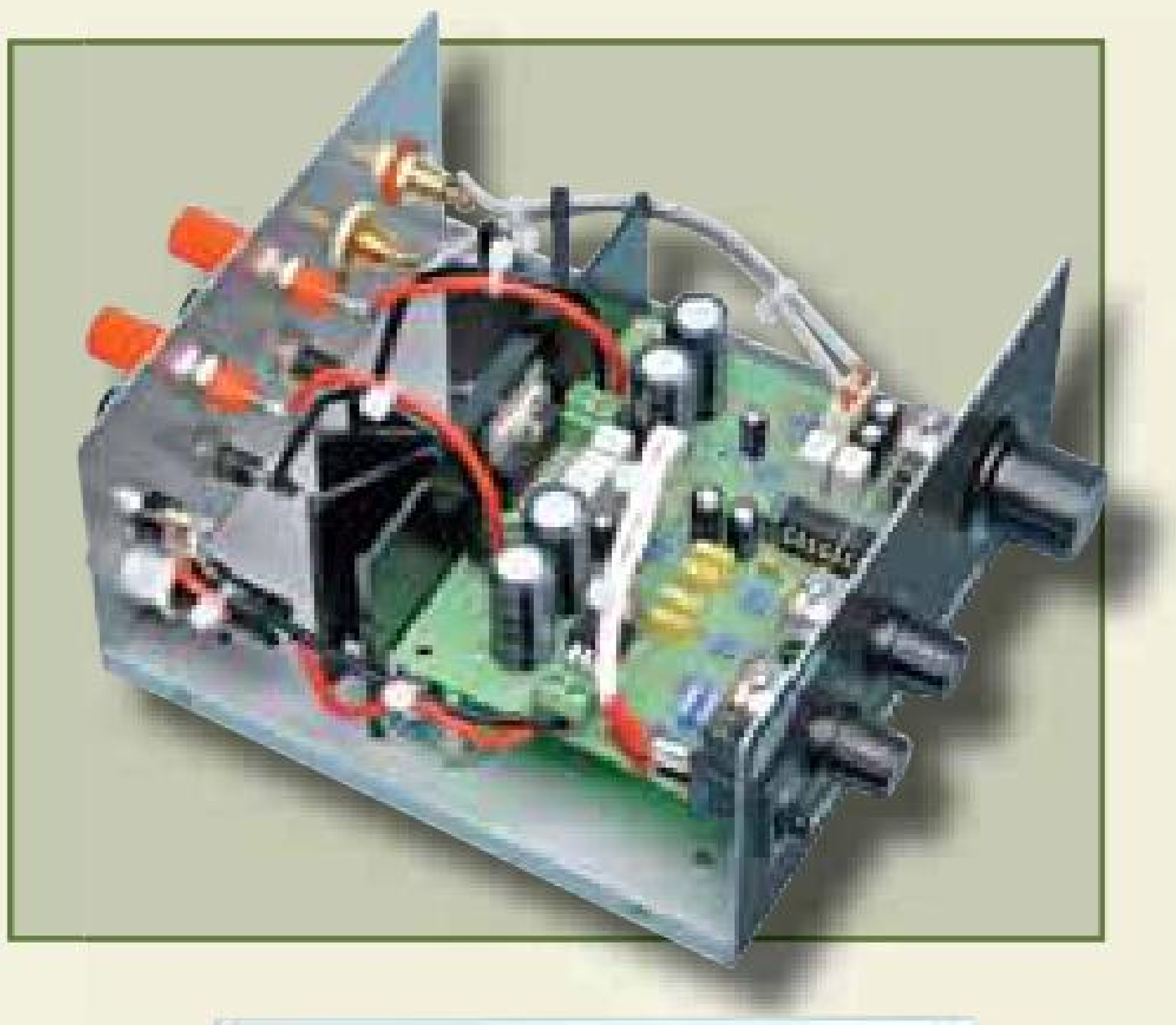

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Our June 2012 issue will be published on Thursday 3 May 2012, see page 80 for details.

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PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU121) £24.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£59.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

USB Flash/OTP PIC Programmer

USB PIC programmer for a wide range of Flash & OTP devices—see website for details. Free Windows Software. ZIF Socket and USB lead not included. Supply: 16-18Vdc.
Assembled Order Code: AS3150 - **£49.95**
Assembled with ZIF socket Order Code: AS3150ZIF - **£64.95**

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board

Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£39.95**

PIC Programmer & Experimenter Board

The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£39.95**
Assembled Order Code: VM111 - **£59.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU303 £9.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055KT - **£39.95**
Assembled Order Code: VM110 - **£64.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two *& Ten Channel versions also available.*
Kit Order Code: 3180KT - **£54.95**
Assembled Order Code: AS3180 - **£64.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£24.95**
Assembled Order Code: AS3145 - **£31.95**
Additional DS1820 Sensors - **£4.95 each**

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£14.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£79.95**
Assembled Order Code: AS3140 - **£94.95**

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£74.95**
Assembled Order Code: AS3108 - **£89.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£64.95**
Assembled Order Code: AS3142 - **£74.95**

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU303). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£37.95**
Assembled Order Code: AS3153 - **£49.95**

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 3191KT - **£27.95**
Assembled Order Code: AS3191 - **£37.95**

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software.
Kit Order Code: 3190KT - **£84.95**
Assembled Order Code: AS3190 - **£99.95**

40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£29.95**
Assembled Order Code: AS3188 - **£37.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**

Video Signal Cleaner

Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£32.95**
Assembled Order Code: VM106 - **£49.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

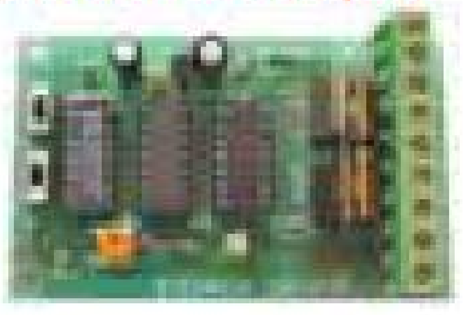
Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

DC Motor Speed Controller (100V/7.5A)

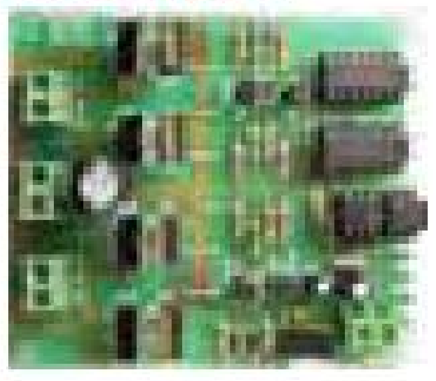
Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£19.95**
Assembled Order Code: AS3067 - **£27.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver



Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£16.95**
Assembled Order Code: AS3179 - **£23.95**

Computer Controlled Bi-Polar Stepper Motor Driver



Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£24.95**
Assembled Order Code: AS3158 - **£34.95**

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166v2KT - **£23.95**
Assembled Order Code: AS3166v2 - **£33.95**

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
Kit Order Code: 1074KT - **£15.95**
Assembled Order Code: AS1074 - **£23.95**

See www.quasarelectronics.com for lots more motor controllers

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Order Code EPL500 - **£199.95**
Also available: 30-in-1 **£19.95**, 50-in-1 **£29.95,** 75-in-1 **£39.95** £130-in-1 **£49.95** & 300-in-1 **£89.95** (see website for details)

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Advanced Personal Scope 2 x 240MS/s

Features 2 input channels - high contrast LCD with white backlight - full auto set-up for volt/div and time/div - recorder roll mode, up to 170h per screen - trigger mode: run - normal - once - roll ... - adjustable trigger level and slope and much more.
Order Code: APS230 - ~~£499.95~~ £399.95

Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use.
Order Code: HPS10 - ~~£189.95~~ £159.95

See website for more super deals!

No.1 FOR KITS

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Everyday Practical Electronics

FEATURED KITS

May 2012

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested Down Under. All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

Digital Audio Delay Kit

KC-5506 £36.25 plus postage & packing

Corrects sound and picture synchronization ("lip sync") between your modern TV and home theatre system. Features an adjustable delay from 20 to 1500ms in 10ms steps, and handles Dolby Digital AC3, DTS and linear PCM audio with sampling rate of up to 48kHz. Connections include digital S/PDIF and optical Toslink connections, and digital processing means there is no audio degradation. Kit includes PCB with overlay and pre-soldered SMD IC, enclosure with machined panels, and electronic components.

- 9-12VDC power supply required
- Universal IR remote required - use AR-1729 £8.75
- PCB: 103(L) x 118(W)mm

NEW

Featured in EPE April 2012

Switching Regulator Kit

KC-5508 £14.50 plus postage & packing

Outputs 1.2 to 20V from a higher voltage DC supply at currents up to 1.5A. It is small, efficient and with many features including a very low drop-out voltage, little heat generation, electronic shutdown, soft start, thermal, overload and short circuit protection. Kit supplied with PCB, pre-soldered surface mounted components and PCB mount components.

- PCB: 49.5(L) x 34(W)mm

Featured in EPE April 2012

Voltage Monitor Kit

KC-5424 £8.50 plus postage & packing

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features 10 LEDs that illuminate in response to the measured voltage, preset 9-16V, 0.-5V or 0-1V ranges, complete with a fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay, LED bar graph and all electronic components.

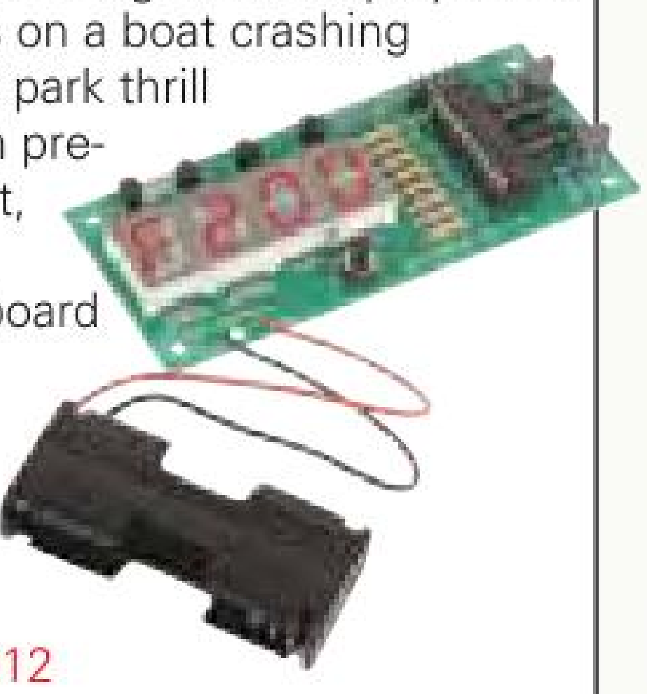
- PCB: 74(L) x 47(W)mm
- 12VDC
- Recommended box: UB5 use HB-6015 £1.25

Featured in EPE February 2012

G-Force Meter Kit

KC-5504 £18.25 plus postage & packing

Measure the g-forces on your vehicle and it's occupants during your next lap around the race circuit, or use this kit to encourage smoother driving to save petrol and reduce wear & tear. Forces (+/- 2g) are displayed on the 4-digit LED display. Also use it to measure g-forces on a boat crashing over waves or on a theme park thrill ride. Kit includes PCB with pre-mounted SMD component, pre-programmed microcontroller and all onboard electronic components.



- Requires 2 x AA batteries
- PCB: 100(L) x 44(W)mm

Featured in EPE March 2012

Note: We supply the PCB with the SMD component already mounted on the board to save time and frustration.

Class-T Digital Audio Amplifier Module

AA-0228 £11.00 plus postage & packing

Ideal for any audio enthusiast that enjoys building and modifying speaker systems. The PCB is tiny which allows you to incorporate it into a wide variety of speaker systems.

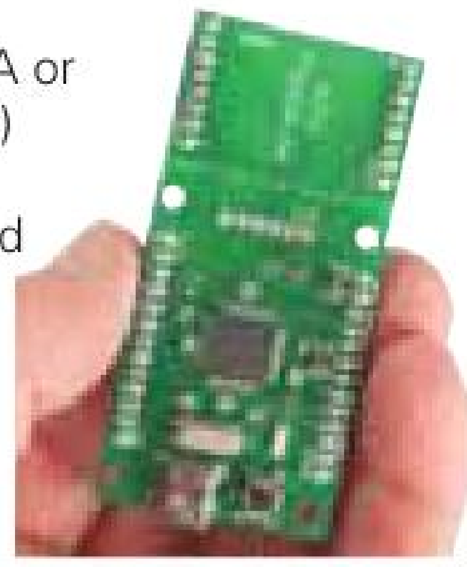
- Regulated 12VDC 2000mA
- Size: 68(L) x 32(W)mm

NEW

Minimaximite Controller Kit

KC-5505 £18.25 plus postage & packing

A versatile and intelligent controller to interface with your creations, such as home automation. Features 20 configurable digital/analog I/O ports, 128K RAM and 256KB flash memory to hold your program and data. Design and test in MMBasic over a USB link from your PC, then disconnect the PC and the programs continue to operate. Alternatively, hard wire a PC monitor, keyboard, SD card reader and amplified speaker to work independent of a PC.



- Requires 2.3 - 3.6VDC (2 x AA or use plugpack MP-3310 £7.00)
- Kit supplied with PCB, pre-programmed and pre-soldered micro, and electronic components
- PCB: 78(L) x 38(W)mm

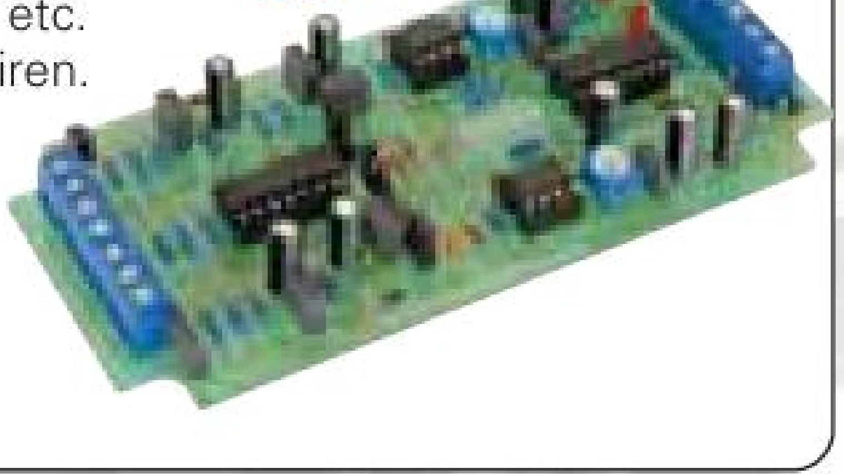
Featured in EPE March 2012

Solar Powered Shed Alarm Kit

KC-5494 £11.00 plus postage & packing

Not just for sheds, but for a location where you want to keep undesirables out but don't have access to mains power e.g a boat on a mooring. It has 3 inputs so you can add extra sensors as required, plus all the normal entry/exit delay etc. Short form kit only - add your own solar panel, SLA battery, sensors and siren.

MORE INFO AVAILABLE ONLINE



- Supply voltage: 12VDC
- Current: 3mA during exit delay; 500µA with PIR connected
- Alarm period: approximately 25 seconds to 2.5 minutes adjustable

Featured in EPE March 2012

45 Second Voice Recorder Module

KC-5454 £12.75 plus postage & packing

Will record two, four or eight different messages for random-access playback or a single message for "tape mode" playback. It also provides cleaner and glitch-free line-level audio output suitable for feeding an amplifier or PA system. It can be powered from any source of 9 - 12VDC.

- PCB: 120(L) x 58(W)mm
- Supplied with silk screened and solder masked PCB and all electronic components

Featured in EPE February 2011

High Performance 12V Stereo Amplifier

KC-5495 £16.50 plus postage & packing

An ideal project for anyone wanting a compact and portable stereo amp where 12V power is available. No mains voltages, so it's safe as a schoolie's project or as a beginner's first amp. Performance is excellent with 20WRMS per channel at 14.4V into 4 ohms and THD of less than 0.03%. Shortform kit only.

- PCB Dimensions: 95(L) x 78(W)mm
- 12VDC
- Recommended heatsink Cat No. HH-8570 £2.25

Featured in EPE next month!

Ultrasonic Antifouling for Boats

KC-5498 £90.50 plus postage & packing

Marine growth electronic antifouling systems can cost thousands. This project uses the same ultrasonic waveforms and virtually identical ultrasonic transducers mounted in a sturdy polyurethane housings. By building it yourself (which includes some potting) you save a fortune! Standard unit consists of control electronic kit and case, ultrasonic transducer, potting and gluing components and housings. The single transducer design of this kit is suitable for boats up to 10m (32ft); boats longer than about 14m will need two transducers and drivers. Basically all parts supplied in the project kit including wiring. (Price includes epoxies).

- 12VDC
- Suitable for power or sail
- Could be powered by a solar panel/wind generator
- PCB: 104(L) x 78(W)mm

Featured in EPE March 2012

Now available Pre-built:
Dual output, suitable for vessels up to 14m (45ft)
YS-5600 £309.25
Quad output, suitable for vessels up to 20m (65ft)
YS-5602 £412.25

Jaycar Electronics

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Arduino - Simple to Advanced Projects

ARDUINO DEVELOPMENT KITS

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs (includes Jaycar stepper motors). Arduino projects can be stand-alone, or they can be communicated with software running on your computer. These Arduino development kits are 100% Arduino compatible. Designed in Australia and supported with tutorials, guides, a forum and more at www.freetronics.com. A very active worldwide community and resources are available with many projects, ideas and programs available to freely use.

"Eleven" Arduino-compatible development board

XC-4210 £14.50 plus postage & packing

An incredibly versatile programmable board for creating projects. Easily programmed using the free Arduino IDE development environment, and can be connected into your project using a variety of analog and digital inputs and outputs. Accepts expansion shields and can be interfaced with our wide range of sensor, actuator, light, and sound modules.

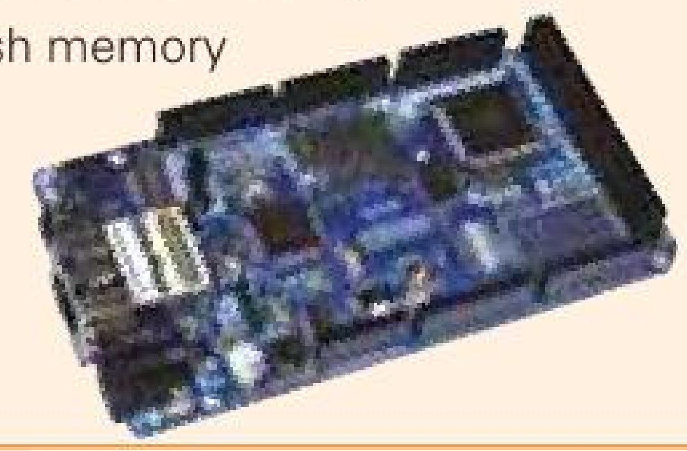
- ATmega328P MCU running at 16MHz
- 14 digital I/O lines (6 with PWM support)
- 8 analog inputs

EtherMega, Mega sized Arduino compatible with Ethernet

XC-4256 £43.25 plus postage & packing

The ultimate network-connected Arduino-compatible board: combining an ATmega2560 MCU, onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, Power-over-Ethernet support, and even an onboard switchmode voltage regulator so it can run on up to 28VDC without overheating.

- ATmega2560 MCU running at 16MHz, large Flash memory
- 10/100base-T Ethernet built in
- 54 digital I/O lines
- 16 analog inputs
- MicroSD memory card slot
- Prototyping area
- Switchmode power supply



USBDroid, Arduino-compatible with USB-host support

XC-4222 £25.50 plus postage & packing

This special Arduino-compatible board supports the Android Open Accessory Development Kit, which is Google's official platform for designing Android accessories. Plugs straight into your Android device and communicates with it via USB. Includes a built-in phone charger.

- ATmega328P MCU running at 16MHz
- USB host controller chip
- Phone charging circuit built in
- 14 digital I/O lines (6 with PWM support)
- 8 analog inputs
- MicroSD memory card slot

EtherTen, Arduino-compatible with Ethernet

XC-4216 £25.50 plus postage & packing

This Arduino-compatible development board includes onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, and even Power-over-Ethernet support.

- ATmega328P MCU running at 16MHz
- 10/100base-T Ethernet built in
- Used as a web server, remote monitoring and control, home automation projects
- 14 digital I/O lines (6 with PWM support)
- 8 analog inputs

Getting Started with Arduino

BM-7130 £7.25 plus postage & packing

This book explains what Arduino is, how it works and what you can do with it. It also includes a project to build, complete with how to write the code to make it work.

- Softcover, 118 pages. 216 x 140mm

Arduino Modules

We have a huge range of simple to advanced add-ons that provide input for your Arduino projects. Visit our website for our full range and more details.

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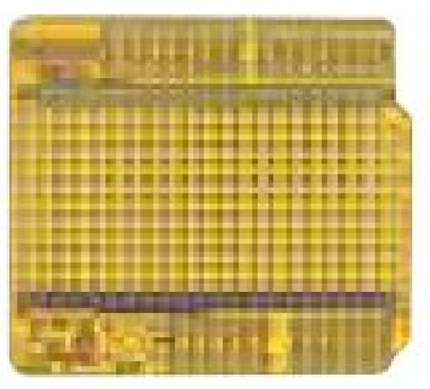
3-Axis Accelerometer Module	XC-4226 £7.25
Humidity & Temperature Sensor Module	XC-4246 £7.25

ProtoShield Basic

XC-4214 £1.75 plus postage & packing

A prototyping shield for the Eleven (XC-4210) and USBDroid (XC-4222) both featured above. Provides plenty of space to add parts to suit any project, keeping everything neat and self-contained. Includes dedicated space to fit a power LED and supply decoupling capacitor.



- Gold-plated surface

Large Dot Matrix Display Panel

XC-4250 £14.50 plus postage & packing

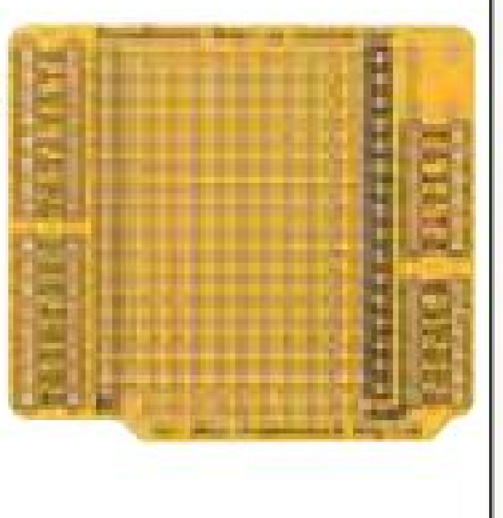
A huge dot matrix LED panel to connect to Eleven, EtherTen and more! This bright 512 LED matrix panel has on-board controller circuitry designed to make it easy to use straight from your board. Clocks, status displays, graphics readouts and all kinds of impressive display projects are ready to create with this display's features.

- 32(L) x 16(W)mm high brightness Red LEDs (512 LEDs total) on a 10mm pitch
- 5V operation
- Viewable over 12 metres away
- Tough plastic frame
- Controller IC's on board, simple clocked data interface
- Arduino compatible library, graphics functions and example support

ProtoShield Short

XC-4248 £2.00 plus postage & packing

A dedicated short version prototyping shield for EtherTen and EtherMega. This special prototyping shield is designed to fit neatly behind the RJ45 Ethernet jack, allowing you to stack your Ethernet-based projects right on top with standard headers.



- Pads available to fit a reset button
- Gold-plated surface for maximum durability

Receiver Shield 433MHz

XC-4220 £11.00 plus postage & packing

This receiver shield lets you intercept 433MHz OOK/ASK signals, decoding them in software on your Arduino. All the Arduino headers are broken out to solder pads, and GND and 5V rails are provided for convenience.

- Reset button
- Blue "power" LED
- Red and green user-defined LEDs
- Gold-plated surface
- 433MHz tuned frequency

LCD & Keypad Shield

XC-4218 £11.00 plus postage & packing

Handy 16-character by 2-line display ready to plug straight in to your Arduino, with a software-controllable backlight and 5 buttons for user input. The display is set behind the shield for a low profile appearance and it includes panel mounting screw holes in the corners.

- 2 rows of 16 characters
- Supported by a driver library
- Software-controlled backlight
- Reset button
- Dimensions: 85(W) x 54(H) x 12(D)mm (24mm including header pins)

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Heatsink for kit £9.95
VM100 Module £38.54

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Plays MP3 files from an SD card, supports ID3 tag which can be displayed on optional LCD. Line & headphone output. Remote control add-on. Power: 12Vdc 100mA
K8095 Velleman kit £39.99

DC to Pulse width Modulator
A handy kit to accurately control DC motors etc. Overload & short circuit protection. Input voltage 2.5-35Vdc, Max output 6.5A.
Power: 8-35Vdc
K8004 Velleman kit £9.95

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TL-5 Cebek Module £14.64

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TL-1 Cebek Module £28.25

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Power: 12Vdc 90mA.
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Compact mono 1.8W RMS 4Ω power stage, short circuit & reverse polarity protection. 30-18kHz, Power: 4-14Vdc 150mA
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Power: 8-18Vdc 2A
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Power: 12Vdc 60mA
I-4 Cebek Module £13.98

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Power: 12Vdc 60mA
I-6 Cebek Module £13.08

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I-8 Cebek Module £12.80

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All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

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Raspberry Pi

It's not easy to beat the 24-7 BBC news machine to a story in a monthly print magazine, but it was nice to see we did just that with our Raspberry Pi coverage back in the March issue. This cheap, but powerful computer is now on sale, and demand is so high that sales are currently restricted to one device per customer. As soon as demand eases a little, suppliers say they will ship multiple Pi computers to anyone requesting more.

Assuming Pi is the British engineering success story we all hope it will be, we would like to devise some projects around it and would welcome ideas from you, our readers. Top of our current list of projects is a follow up to the popular WIB server project we ran from December last year – a Pi-based server sounds exciting. Remember, Pi comes with built-in USB, LAN, audio/video outputs and an SD card slot, so there's plenty of scope for sophisticated, flexible designs. What would you like to see Pi used for?

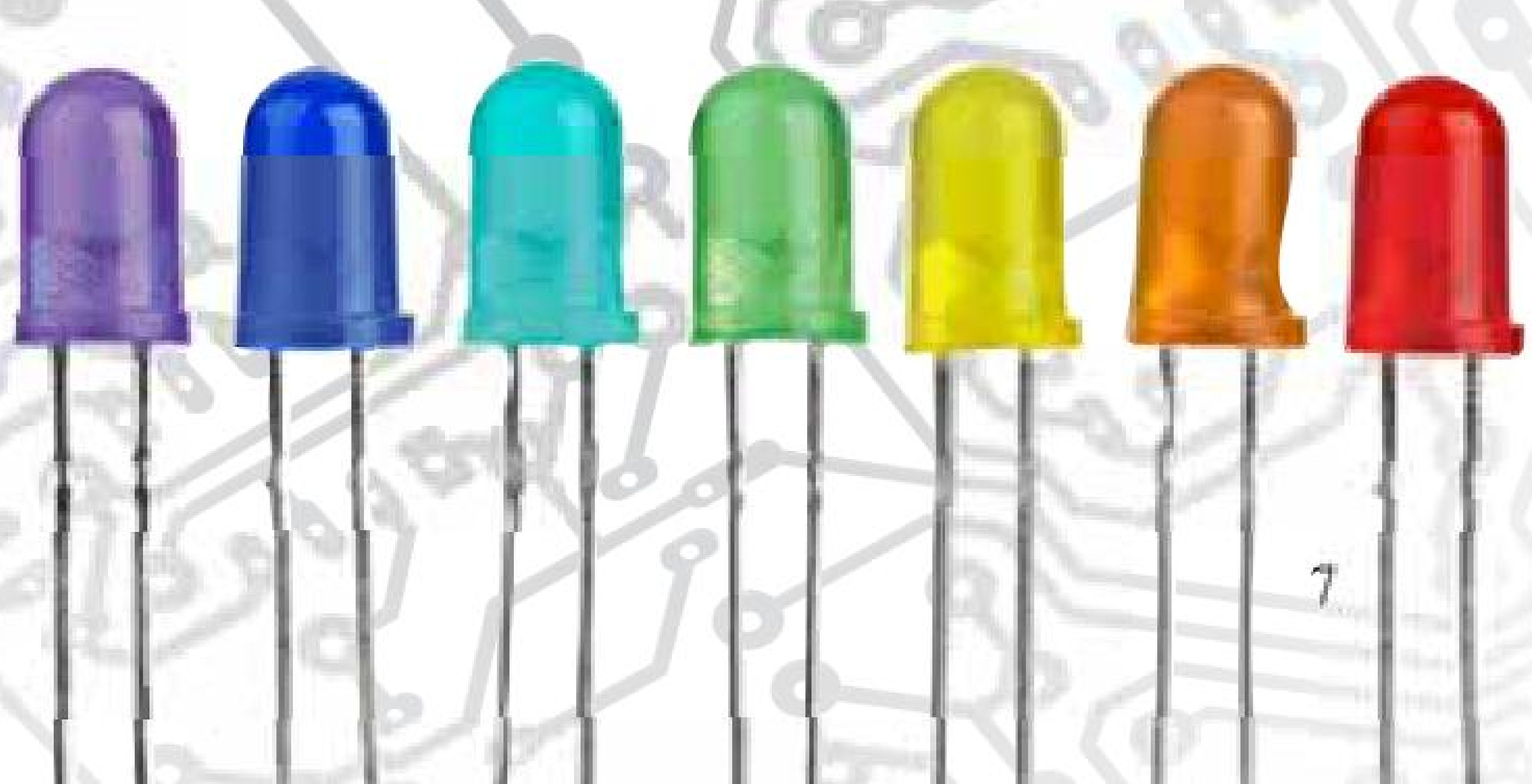
Jump Start launch

This issue sees an expanded *EPE* launching *Jump Start*, our series dedicated to newcomers to electronics. If you are a seasoned 'old hand' at using silicon, why not help a friend, son or daughter get into electronics with this project series? You'll have fun and help to spread the word that there is more to hobby-related electronics than shooting on-screen aliens or updating a Facebook profile!

EHT probe

We have received a few queries about last month's extra high tension (voltage) probe. Unfortunately, they arrived too late to be included in this month's *EPE*, but we will include a couple next month. However, the questions mostly boil down to 'is it safe?', and I'd like to take this opportunity to make a few comments. First, yes the probe is safe – but, and it's an important 'but', only if built and used properly. Second, it is vital that constructors follow the instructions in the article. This is not the kind of projects where you can cut corners or use cheap resistors – the more expensive, higher rated ones were chosen for good safety and functionality reasons.

Last, but not least, this is NOT a beginner's project. If you are new to electronics, steer well clear of mains electricity and always avoid especially very high voltages. You need experience to tackle dangerous voltages, and the best way to get this is through training or the advice and guidance of a colleague/friend whose opinion you have good reason to trust.



NEWS

A roundup of the latest Everyday News from the world of electronics

Time for DRM, or has it missed the boat? by Barry Fox

For the last ten years, Digital Radio Mondiale (DRM) has been just around the corner. DRM is a European system for broadcasting decent-quality digital radio on existing short wave, AM and FM frequencies. It's technically clever, but I have several times got egg on face by reporting that DRM receivers are finally ready for sale, when it turned out they weren't. The false promises flow mainly from the stream of upbeat news releases that gush from the DRM Consortium, currently with an office inside the BBC's Bush House and enthusing that 'New year 2012 couldn't have had a better start.'

The DRM people can regularly be seen at industry shows, displaying DRM receivers and promoting news like 'the ITU's endorsement of DRM+', 'the first multi-standard processor for car radios which includes DRM has just been launched' and 'DRM+ has been tested in Rome by Vatican Radio.'

'Big events are lined up in New Delhi, Kuala Lumpur, Geneva and Las Vegas' says DRM, 'not to mention the DRM General Assembly to be held in the UK in March.'

DRM is sound technology, but no one has yet broken the chicken and egg circle. Without broadcasts, manufacturers won't make receivers comparable to the sub-£100 DAB boxes from Pure that kick-started DAB in the UK.

Both the BBC and RTL Radio Luxembourg have variously promised big push DRM services, but they never quite happen. Now faith is pinned on Radio Vatican.

In 2004, DRM announced that 'a new DRM receiver will be officially introduced at IBC this coming weekend.', see: **www.codingtechnologies.com/news/assets/2004/20040901_drmusbrec_eng.pdf**

In 2005, DRM promised receivers 'to be showcased at the DRM Stand at Le Radio! this year'. These included 'AYAH's DRM 2010 receiver, a second generation receiver (which) is a joint development by Coding Technologies, BBC R&D, and DRM Supporters MAYAH and AFG Engineering GmbH. DRM member, the BBC will display DRM transmissions from the UK to France on short-wave, including an audio-on-demand service. The BBC will also demonstrate a data service that connects to the DRM 2010 via USB. TDF will demonstrate live, local medium-wave transmissions, and will showcase a software receiver.

'The Digital World Traveller from DRM member Coding Technologies' was also promised for 2005. It was 'a small, USB device that connects to a PC or a laptop without needing any additional power supply or battery. It comes with the Digital World Traveller Radio Software, and can receive DRM, FM and AM programs'.

And: 'RadioScape will be launching its new RS500 module for DRM and DAB at the Digital Radio Show at the Islington Business Centre, London on 1-2 June 2005.'

And so it has gone on, year after year. The DRM Consortium has never learned the basic lesson that crying wolf with false dawn promises of non-existent receivers, and never an explanation or apology for the non-appearance, saps trade, press and consumer confidence.

Recently, someone in the DRM Office goofed by sending out a press release that included every recipient's email address. This sparked a free-for-all mix of Reply-All and Personal emails, both attacking and defending the project.

One writer said he was so excited about a new $110 DRM receiver that he 'has many on order so as to give friends.'

Several of us queried the source of these radios. An official spokeswoman for DRM evaded the question by asking 'how many of your friends would like to buy these receivers?'

Finally, we squeezed out the facts. The radios will come from China, with 'estimated' availability in April. And the $110 price is FOB China for a minimum of one thousand receivers.

WORLD SERVICE

Selection of BBC World Service Programmes

While DRM has many advantages, it may simply be leapfrogged by Internet radio,which unlike DRM is widely available and requires no new technology base

This could be a step in the right direction for DRM, but it's not quite the commercial breakthrough which has been portrayed.

And all the time, Internet radio is taking over from long distance broadcasting.

World's most energy-efficient processor

ARM in Cambridge, UK has announced the ARM Cortex-M0+ processor, which it claims is the world's most energy-efficient microprocessor. The Cortex-M0+ has been optimised to deliver ultra low-power, low-cost microcontrollers for intelligent sensors and smart control systems in a broad range of applications, including home appliances, white goods, medical monitoring, metering, lighting and power and motor control devices.

The 32-bit Cortex-M0+ processor, is the latest addition to the ARM Cortex processor family; it consumes just 9µA/MHz, around one third of the energy of any 8- or 16-bit processor available today, while delivering 32-bit performance.

The aim of the processor is to enable the creation of smart, low-power, microcontrollers to provide efficient communication, management and maintenance across a multitude of wirelessly connected devices, a concept known as the 'Internet of Things'.

This low power connectivity has the potential to enable a range of energy-saving applications from sensors that wirelessly analyse the performance and control of domestic or industrial buildings, to battery-operated body sensors wirelessly connected to health monitoring equipment. Current 8-bit and 16-bit MCUs lack the intelligence and functionality to deliver these applications.

'The Internet of Things will change the world as we know it, improving energy efficiency, safety, and convenience,' said Tom Halfhill, senior editor of *Microprocessor Report*. 'Ubiquitous network connectivity is useful for almost everything – from adaptive room lighting and online video gaming to smart sensors and motor control. But it requires extremely low-cost, low-power processors that can still deliver good performance.' ARM hopes that their new Cortex-M0+, which brings 32-bit horsepower to flyweight chips will answer this need.

GPS jammers threaten positioning reliability

A study has revealed the use of illegal Global Positioning System (GPS) jammers in the UK. The jammers are mostly used by people driving vehicles fitted with tracking devices who wish to mask their location and/or journey details.

The study was conducted over concerns that jammers – which are widely available online – could interfere with critical systems which rely on GPS. Roadside monitors were used to detect jammer use, which are typically small, relatively low power portable devices with a working range of 200 to 300m.

Radio communication with a twist

The famous lagoon in Venice, Italy, where Galileo first publicly demonstrated his telescope has been the scene of another potential revolution in technology. Bo Thide of the Swedish Institute of Space Physics and a team of colleagues in Italy have shown experimentally that it is possible to use two beams of incoherent radio waves, transmitted on the same frequency but encoded in two different orbital angular momentum states, to simultaneously transmit two independent radio channels. According to their article in the *New Journal of Physics*, 'this novel radio technique allows the implementation of, in principle, an infinite number of channels in a given, fixed bandwidth, without even using polarisation, multiport or dense coding techniques. The designers of the simple technique hope it paves the way for innovative techniques in radio science and entirely new paradigms in radio communication protocols that might offer a solution to the problem of radio-band congestion.'

Thide's modified satellite dish

The team managed to give electromagnetic waves a 'twist' by splitting one side of a standard satellite dish with a radial cut and pulling the two edges apart to create a rough corkscrew transmitter – or 'helicoidal parabolic antenna', to give it its technical name .

Thide and his colleagues are hoping to exploit their innovation with the communications industry.

Small, smaller, smallest...

Miniaturisation has been one of the key enabling ideas of electronics – even in the pre-silicon era, reducing the size of vacuum tubes was an aim of designers to help create more powerful radio and radar technologies for planes in the Second World War.

The search for smaller never stops; two recent announcements have emphasised this trend. Scientists at the University of California, San Diego have used a novel cylinder design to produce the smallest-ever laser that works at the light wavelengths used in telecommunications. The laser's all-important 'cavity' is just 100 billionths of a metre in diameter.

This is a 'giant' compared to the ultimate in tiny transistors. A group of physicists, based at the University of New South Wales and Purdue University, who are working in quantum computing, have built a working transistor from a single phosphorus atom embedded in a silicon crystal.

Geeky jewellery range

COLLECTOR
PNP
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symbols
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similar

How to dress ears in sterling silver stereo

It's true, *EPE* is not normally that interested in jewellery, but we've made an exception for the products of Nicholas and Felice in Philomath, Oregon, US. If you, or someone you know, might fancy an electronics (or mathematics) themed set of earrings or a necklace pendant, then have a quick look at: **www.etsy.com/shop/nicholasandfelice?section_id=5228075**

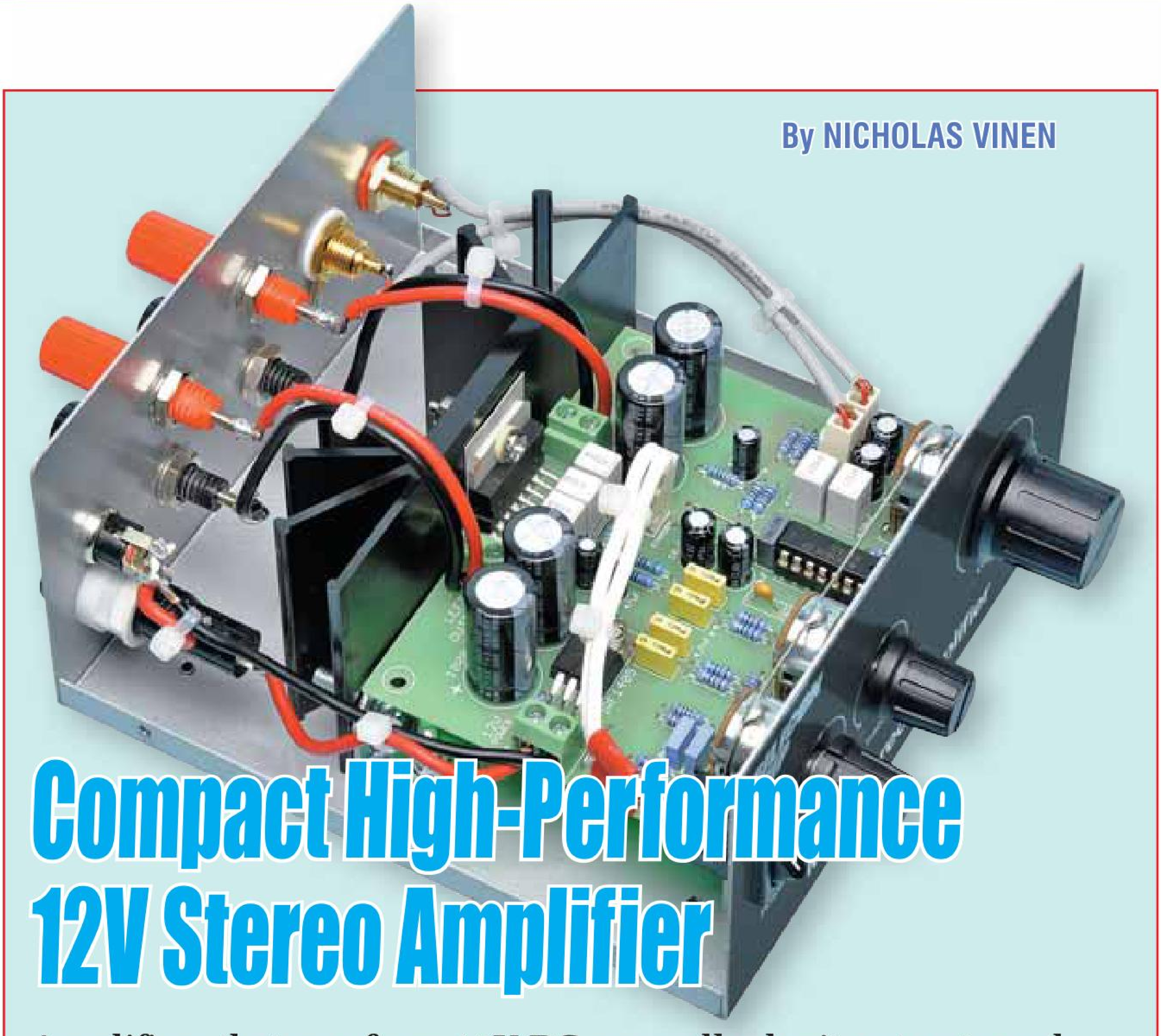
The inexpensive sterling silver pieces have clearly been designed by a couple who know the difference between a diode and a resistor – you can even have a 'matched pair' of *npn/pnp* transistors dangling from your ears for push-pull ornamentation. They might just make the perfect present for you or your silicon-obsessed significant other!

EPE EVERYDAY PRACTICAL ELECTRONICS

If you have some breaking news you would like to share with our readers, then please email:

editorial@wimborne.co.uk

By NICHOLAS VINEN



Compact High-Performance 12V Stereo Amplifier

Amplifiers that run from 12V DC generally don't put out much power, and they are usually not 'hifi' either. But this little stereo amplifier ticks the power *and* low distortion boxes. With a 14.4V supply, it will deliver 20W per channel into 4Ω loads at clipping, while harmonic distortion at lower power levels is typically less than 0.03%.

THIS IS an ideal project for anyone wanting a compact stereo amplifier that can run from a 12V battery. It could be just the ticket for buskers who want a small but gutsy amplifier, which will run from an SLA (sealed lead-acid) battery. Alternatively, it could be used anywhere that 12V DC is available – cars, recreational vehicles, or remote houses with 12V DC power.

Since it runs from DC, it will be an ideal beginner's or school project, with no 230V AC power supply to worry about. You can run it from a 12V battery or a DC plugpack. But while it may be compact and simple to build, there is no need to apologise for 'just average' performance. In listening tests from a range of compact discs, we were very impressed with the sound quality.

The bottom line – this amp has a THD under typical conditions of just 0.03% or less (see Performance figures on page 63). Also, its idle power consumption is low – not much more than 1W. Therefore, if you don't push it too hard, it will run cool and won't drain the battery quickly. And because the IC has self-protection circuitry, it's just about indestructible. It will self-limit or shut down if it overheats, and the outputs are deactivated if they are shorted.

Obtaining enough power

With a 12V supply, the largest voltage swing a conventional solid-state power amplifier can generate is ±6V. This results in a meagre 4.5W RMS into 4Ω, and 2.25W RMS into 8Ω, without even considering losses in the output transistors. Even if the DC supply is around 14.4V (the maximum that can normally be expected from a 12V car battery), that only brings the power figures up to 6.48W and 3.24W for 4Ω and 8Ω loads respectively – still not really enough.

There are three common solutions to this problem. The first is to boost the supply voltage using a switchmode DC converter. This greatly increases the cost and complexity of the amplifier, but it is one way of getting a lot of power from a 12V supply. However, we wanted to keep this project simple and that rules out this technique.

The second method is to lower the speaker impedance. Some car speakers have an impedance as low as 2Ω, which allows twice as much power to be delivered at the same supply voltage. However, we don't want to restrict this amplifier to 2Ω loudspeakers.

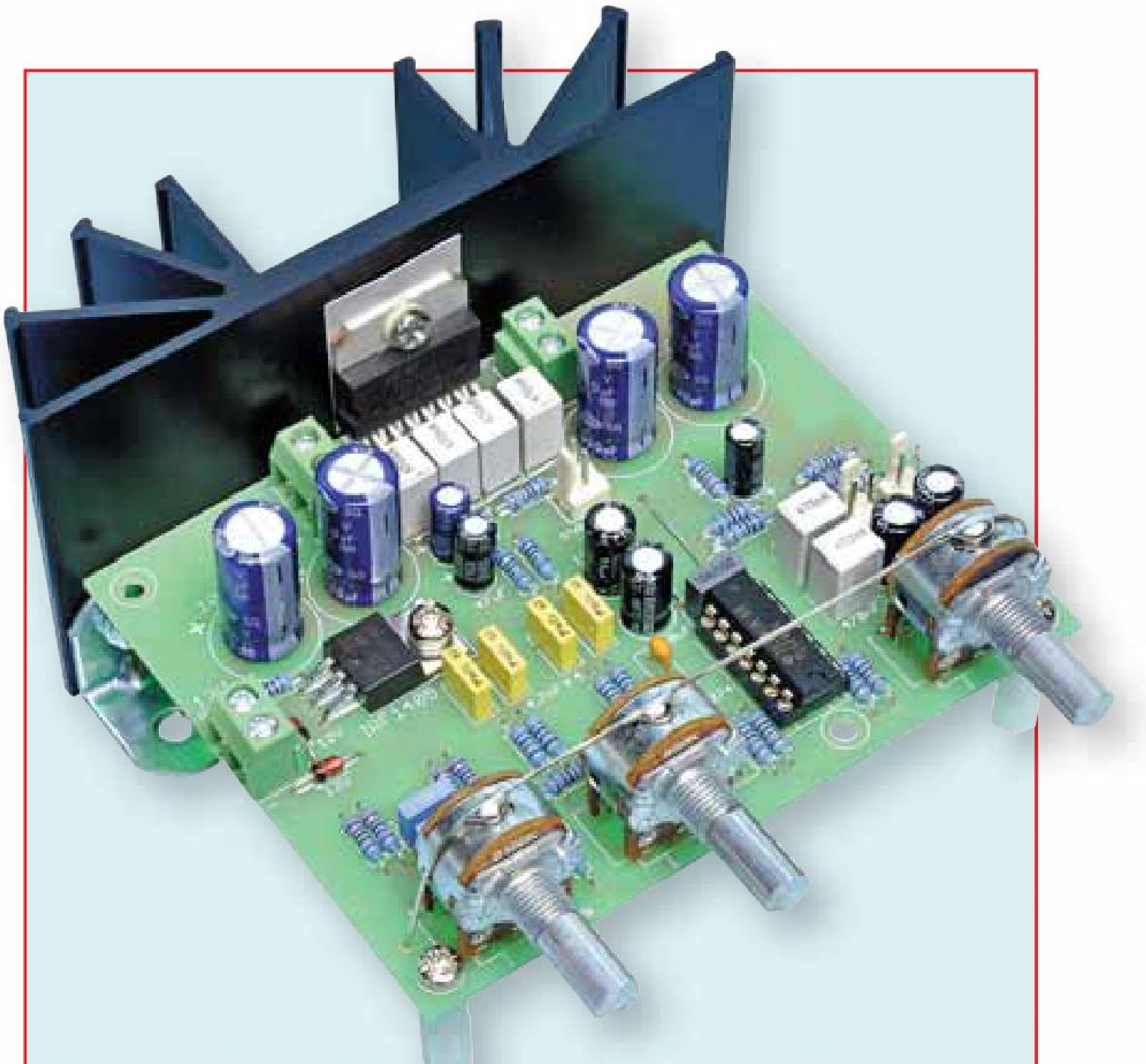
Bridge mode

The remaining solution is to use bridge mode, also known as bridge-tied load (BTL). It requires two amplifier circuits per channel. The TDA-7377 IC is ideal for this purpose – it contains four amplifiers in a single package and is intended for a bridged stereo configuration.

In the TDA7377, two of the four amplifier circuits have inverting inputs, so all we need to do is to feed the same signal to one of each type and the outputs will swing in opposite directions – when one voltage goes up, the other will go down, and *vice versa*.

Instead of connecting the speakers between the amplifier output and ground, we connect them between the two outputs. This doubles the voltage across the speaker and multiplies the maximum power delivered by four ($P = V^2/R$). It also eliminates the AC-coupling capacitor at the output, which is needed with a standard single supply amplifier.

Practically speaking, virtually any 4Ω or 8Ω speaker is suitable for use with this amplifier; the more efficient, the better. Avoid anything less than 4Ω, as that would be asking each amplifier circuit to drive a load under 2Ω, which the IC is not rated for.



It may be small, but the High-Performance 12V Stereo Amplifier puts out up to 20W per channel into 4Ω loads at low distortion. It uses just two ICs and is very easy to assemble.

Circuit description

The full circuit diagram is shown in Fig.3. As can be seen, it's based on the aforementioned TDA7377V monolithic stereo BTL amplifier (IC2) plus a TL074 quad FET-input op amp package (IC1). The latter provides the tone control stages in both channels.

As shown, the input signals are fed via 4.7μF non-polarised (NP) capacitors to a 10kΩ dual-gang potentiometer (VR1), which serves as the volume control. From there, the signals are AC-coupled via 470nF capacitors to op amps IC1a and IC1b. These act as unity-gain buffer stages to provide a low source impedance for the following Baxandall tone control stages based on IC1c and IC1d.

In operation, IC1c and IC1d, and their associated potentiometers (VR2 and VR3), provide bass and treble boost of ±15dB, with a centre frequency of 700Hz. The frequency response is very flat when the pots are centred (see Fig.11).

To understand how the tone control stages work, let's consider the bass and treble sections separately. We'll concentrate on the bass sections first, but will initially ignore the 10nF capacitors. This leaves us with an inverting amplifier (IC1c or IC1d), where the resistors (including the pots) form the feedback network and thus control the gain. With the bass pot (VR2) turned all the way clockwise, the gain is set at 122kΩ/22kΩ, or about 5.5. If it is turned in the opposite direction, the gain is 22kΩ/122kΩ, or 0.18.

Adding the 10nF capacitors across VR2a and VR2b adds a low-pass filter to each gain network, so that turning the knob affects low frequencies more than high frequencies. As a result, we can adjust the gain of the bass and hence achieve bass boost/cut.

The treble section (VR3a and VR3b) works similarly, except that the capacitors (4.7nF in this case) are in series with the resistors, thus forming a high-pass filter instead.

The 10pF capacitors on the inverting inputs of IC1c and IC1d reduce their gain at high frequencies, thereby

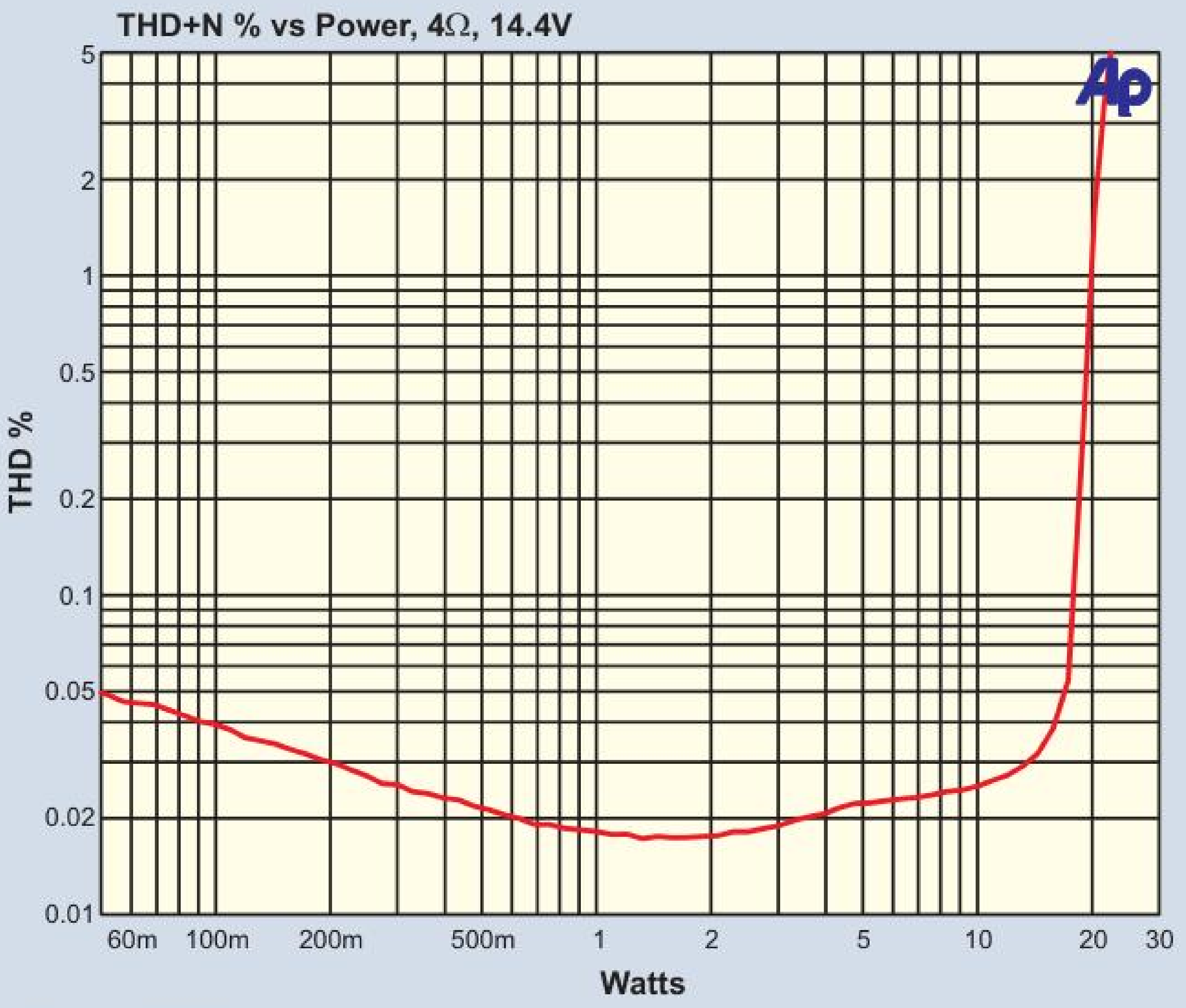


Fig.1: THD+N vs output power at 4Ω (one channel driven only). The supply is 14.4V and the measurement bandwidth is 20Hz to 22kHz. The distortion increase below 1W is due to noise.

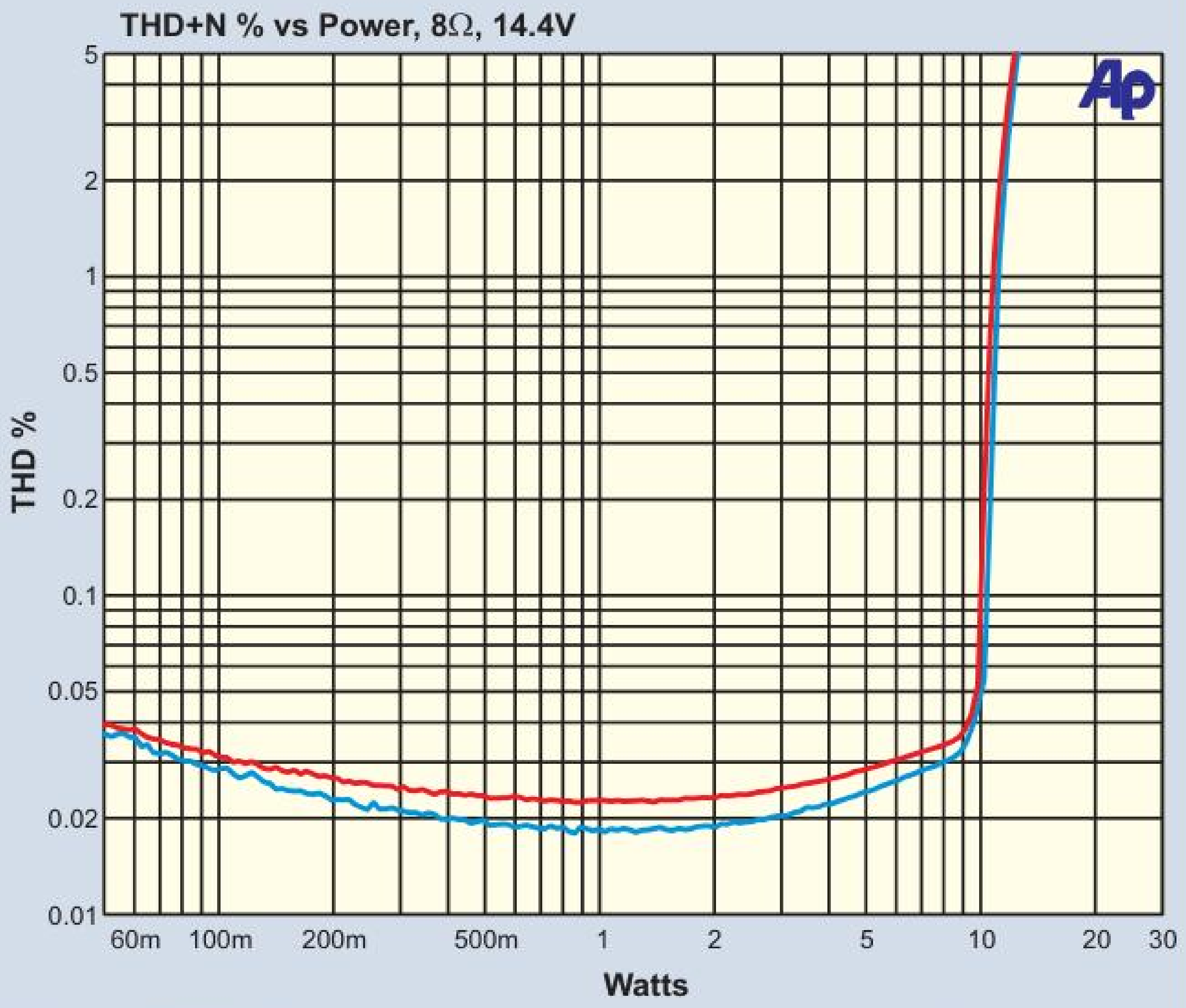


Fig.2: THD+N vs output power at 8Ω with both channels driven. The supply is 14.4V and the measurement bandwidth is 20Hz to 22kHz. The disparity between the channels is primarily due to tone control pot tracking errors.

preventing oscillation in case there is RF pick-up in the filter network. Similarly, the 10Ω resistors at the outputs of IC1c and IC1d attenuate any RF signals which may make it through before they go into the power amplifier (IC2).

Power amplifier

Only a few external components are required by the single TDA7377V quad power amplifier IC (IC2). It's very clever – not only does it contain the four low-distortion amplifiers we need to drive stereo speakers in BTL configuration, but it has virtually rail-to-rail swing on the outputs and is inherently stable with a fixed 26dB gain.

We have used its standby pin (pin 7) to switch the amplifier on and off. This avoids having high current passing through on/off switch S1. In fact, S1 only switches the power to pin 7 of IC2 and to the quad op amp IC1. Hence, the power supply and IC1 remain energised as long as the supply voltage is present, but only the capacitor leakage and standby current are drawn, a total of around 100µA. Switching the amplifier on raises the quiescent (no signal) current to around 100mA.

As soon as switch S1 is turned on, the 100µF filter capacitor is charged via diode D1. The standby pin (pin 7) has a low-pass filter consisting of a 22kΩ resistor and 1µF capacitor, so that the power amplifier is not enabled until the op amp is on. This avoids turn-on thumps.

Similarly, when you switch S1 off, the 22kΩ resistor at the anode of diode D1 pulls down the standby pin voltage, turning the power amplifier IC off almost immediately. This avoids switch-off thumps from the loudspeakers.

Reverse polarity protection

The main power supply components are the four 2200µF 25V electrolytic capacitors, plus two 470nF MKT capacitors in parallel for high-frequency filtering. MOSFET Q1 provides reverse polarity protection for this section.

Although the TDA7377 IC can withstand negative supply voltages, the electrolytic capacitors cannot. So, in this circuit we have connected an IRF1405 MOSFET in series with the supply ground lead.

In essence, the MOSFET acts like a diode with a very low forward voltage, typically less than 25mV at 5A (we measured 8.7mV at 2.5A). This compares with around 1V at 5A for a standard rectifier diode. This means that the amplifier can deliver significantly more power, about 15% more, in fact, than if a standard diode had been used.

Power source

The maximum current consumption depends on the speaker impedance and how far you turn up the volume. As a rough guide, full power with a 14.4V supply and 8Ω speakers requires at least 3A. For 4Ω speakers, the current consumption can exceed 6A.

At a minimum, use a 7.2Ah SLA battery for 8Ω speakers, or a 12Ah SLA for 4Ω. These should last 2 to 24 hours, depending on how hard you're driving the amplifier (larger batteries will last longer).

You can charge the battery while using the amplifier, although this may slightly prejudice the sound quality due to the supply ripple that charging introduces. Power supply rejection is >50dB at 300Hz, and thanks to the large supply bypass capacitors, the additional noise should be kept to a low level.

If you want to run the amplifier from a mains power supply, both linear and switchmode types are suitable. A 6A linear supply is likely to be large and expensive, so switchmode is probably the way to go. A higher supply voltage (ie, up to 16V) will give more power.

The absolute maximum operating voltage is 18V, so make sure whatever you use can never exceed that.

Construction

All the circuit components, including the potentiometers for the volume and

HIGH-PERFORMANCE STEREO AMPLIFIER

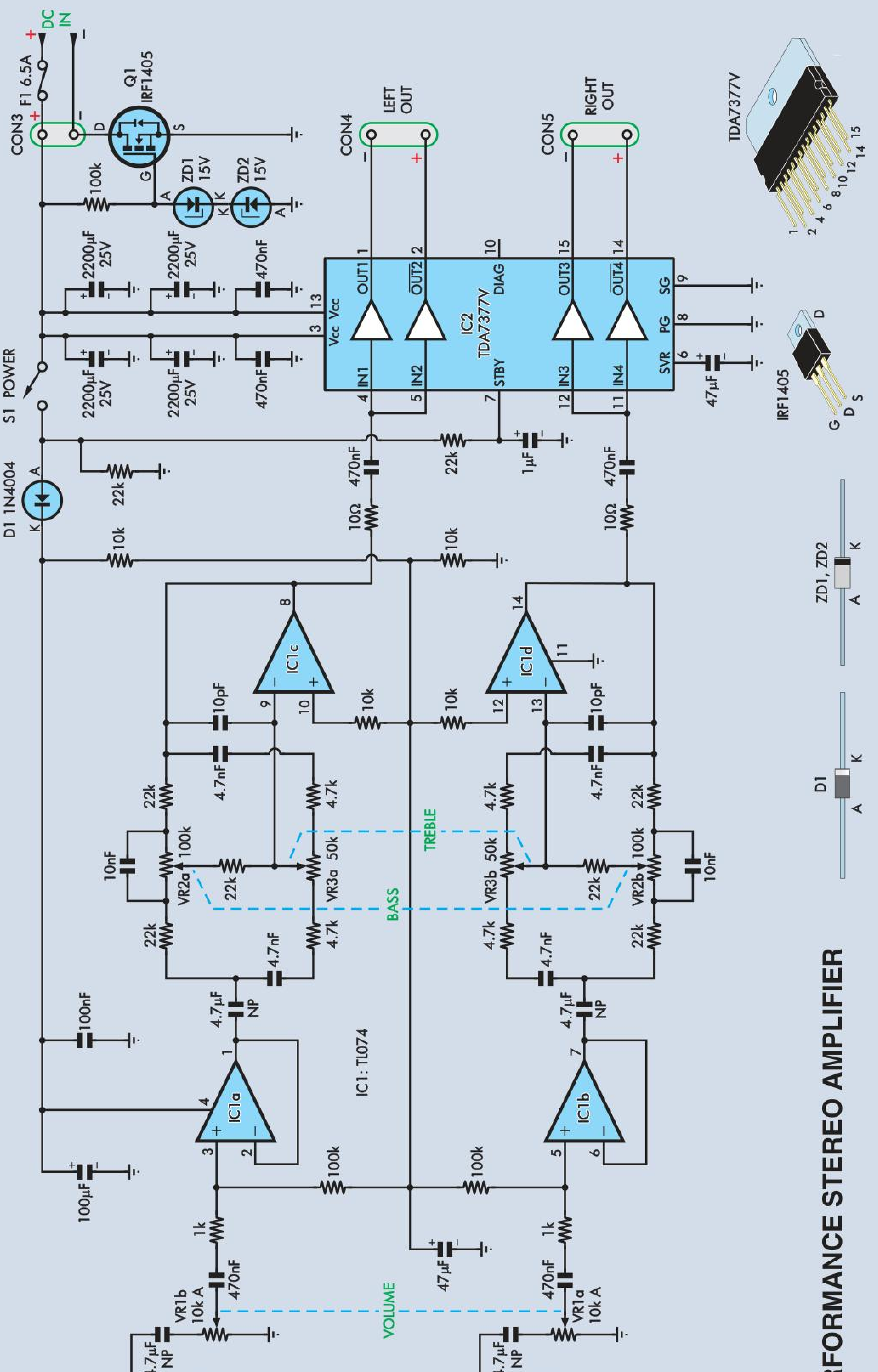

DC IN
F1 6.5A
CON3
Q1 IRF1405
D G S
100k
ZD1 15V
ZD2 15V
A K
2200µF 25V
470nF
S1 POWER
D1 1N4004
22k
10k
CON4
LEFT OUT
CON5
RIGHT OUT
IC2 TDA7377V
Vcc
IN1
IN2
IN3
IN4
OUT1
OUT2
OUT3
OUT4
STBY
DIAG
SVR
PG
SG
47µF
1µF
10Ω
IC1a
IC1b
IC1c
IC1d
IC1: TL074
10pF
4.7nF
4.7k
VR2a 100k
VR2b 100k
VR3a 50k
VR3b 50k
10nF
BASS
TREBLE
100nF
100µF
4.7µF NP
100k
1k
VR1a 10k A
VR1b 10k A
VOLUME
LEFT IN CON1
RIGHT IN CON2
TDA7377V
1 2 4 6 8 10 12 14 15
IRF1405
G D S
ZD1, ZD2
D1

Fig.3: the complete circuit is based on a TL074 quad FET-input op amp (IC1) and a TDA7377V quad power amplifier (IC2). IC1a-IC1d and their associated stereo potentiometers (VR2-VR3) form a Baxandall tone control circuit, and this drives IC2, which is wired in bridged stereo mode. MOSFET Q1 provides reverse polarity protection.

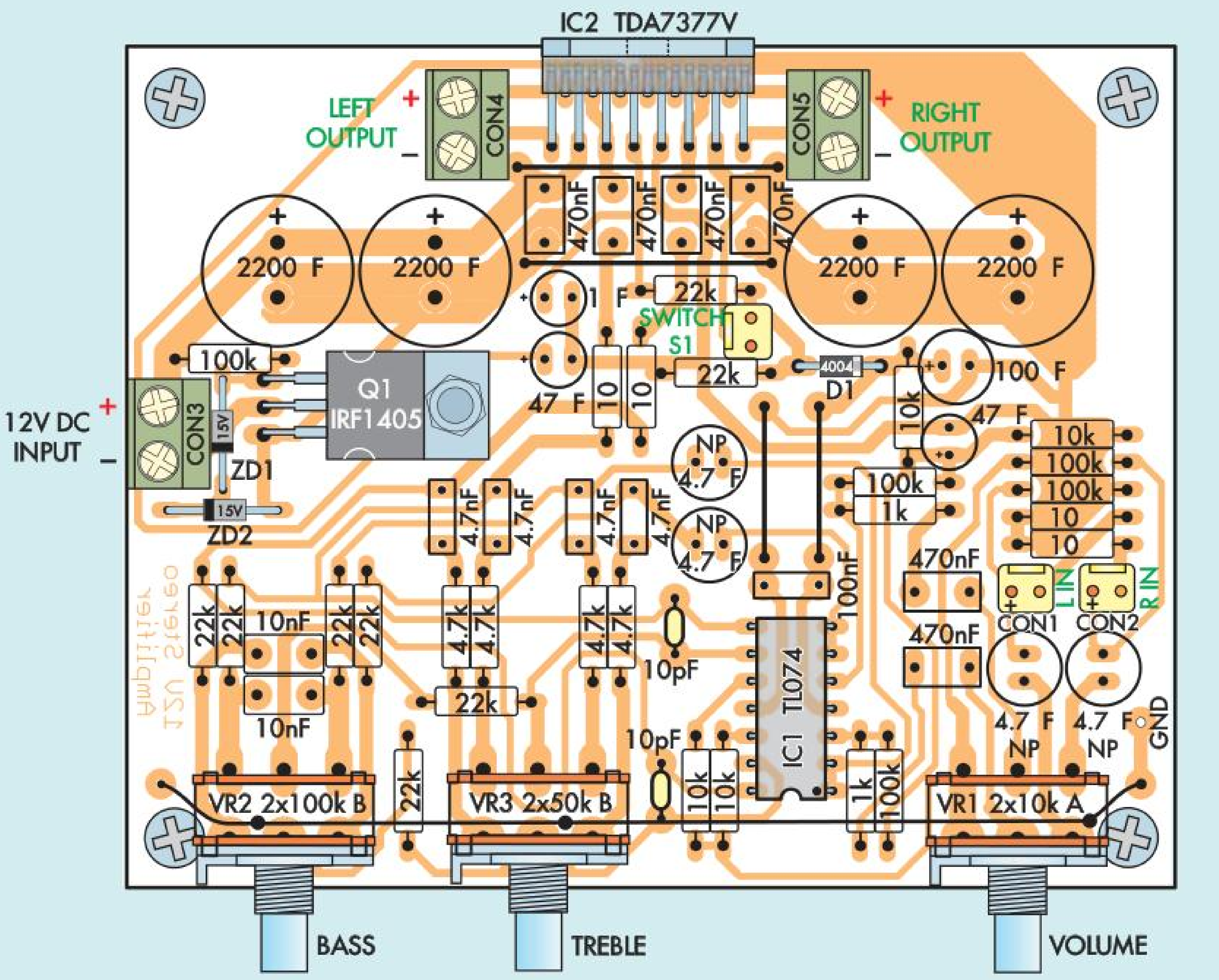
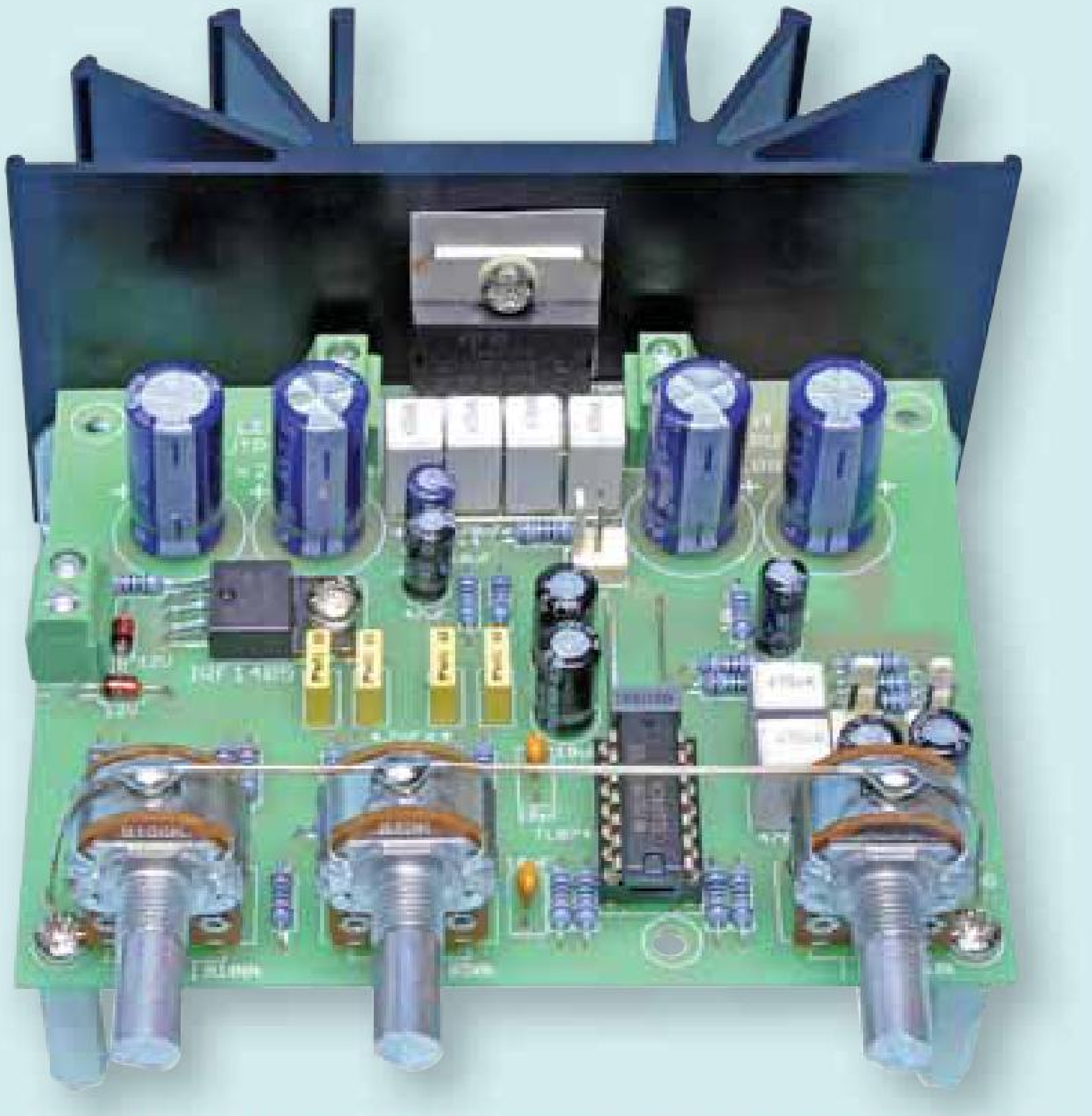

IC2 TDA7377V
LEFT OUTPUT
CON4
CON5
RIGHT OUTPUT
2200µF
470nF
1µF
22k
SWITCH S1
100k
Q1 IRF1405
12V DC INPUT
CON3
15V
ZD1
ZD2
47µF
10
4004
D1
100µF
10k
47µF
NP 4.7µF
4.7nF
100k
1k
470nF
100k
LIN
RIN
CON1
CON2
22k
10nF
4.7k
22k
10pF
IC1 TL074
100nF
4.7µF NP
GND
VR2 2x100k B
VR3 2x50k B
VR1 2x10k A
BASS
TREBLE
VOLUME

Fig.4: follow this layout diagram to build the PC board. Make sure that all polarised parts are correctly oriented and don't get the pots mixed up.



This view shows the completed prototype. The potentiometer bodies are connected together using a length of 'tinned' copper wire, which loops across them and is terminated in pads on either side of the board.

tone controls, are mounted on a single PC board measuring 97mm × 78mm and coded 843. This board is available from the *EPE PCB Service*. The PC board is housed in a compact metal case with an aluminium base and steel lid.

Fig.4 shows the component layout on the PC board. Start by checking the board for defects, such as shorts or breaks in the copper tracks and undrilled holes. If it's OK, start the assembly by installing the four wire links using 0.71mm tinned copper wire. Make sure they are straight and flat before soldering, since some of the links pass near exposed component legs.

Next, install the fixed value resistors. It's a good idea to check each value with a DMM, as the colour codes can be notoriously hard to read.

After that, solder in the two Zener diodes. They are identical, but do make sure that you get their orientation correct.

Once the Zeners are in, bend the MOSFET's leads down at right angles, about 5mm from its metal tab, using small long-nosed pliers. That done, insert its leads into the PC board and check that its mounting hole lines up. Adjust the leads if necessary, then secure the tab to the PC board using an M3 × 6mm machine screw, spring washer and nut. Once it is firmly in place and cannot move, solder and trim the three leads.

Next, install the three terminal blocks. Push them all the way down so that they sit flush with the board and check that they are correctly oriented before soldering their pins. The three polarised headers (CON1, CON2 and S1) can then be installed, again taking care with their orientation.

Follow with the MKT capacitors and the two ceramic types. The polarity doesn't matter here, but don't get the values mixed up. The four bipolar electrolytic capacitors can now be installed, followed by the four small polarised electrolytics. Don't install the larger 2200µF units just yet.

Next, install the TL074 IC, making sure it goes in the correct way around. We used a socket in our prototype, but there's no reason why it cannot be directly soldered to the PC board.

Installing the TDA7377

It's now time to install the TDA7377V. You must do this slowly and carefully since it's difficult to remove if it's misaligned.

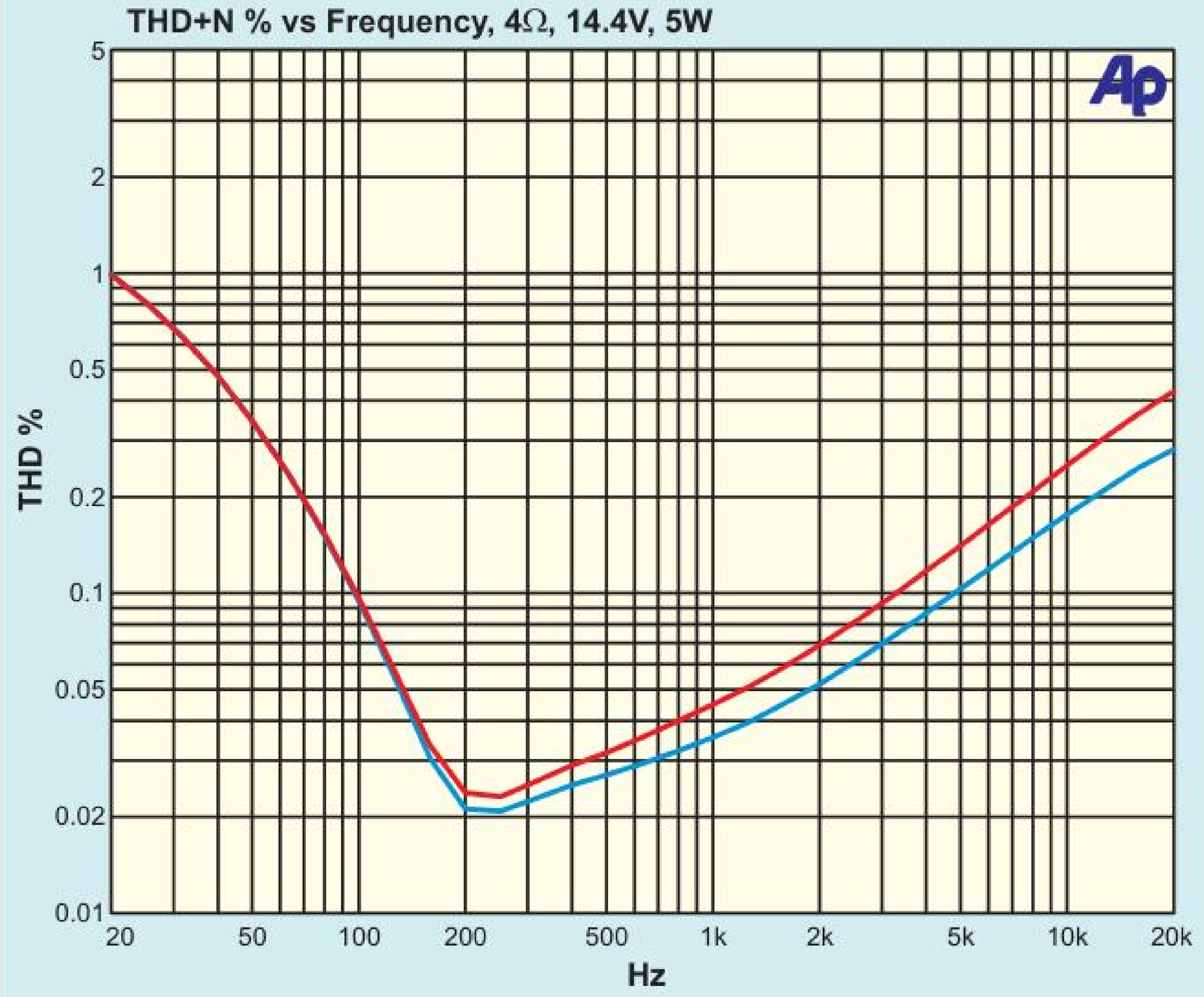


Fig.5: THD+N vs frequency for 5W into 4Ω. The supply is 14.4V and the measurement bandwidth is <10Hz-80kHz. The reading at 1kHz is slightly higher than in Fig.1 due to the wider measurement bandwidth.

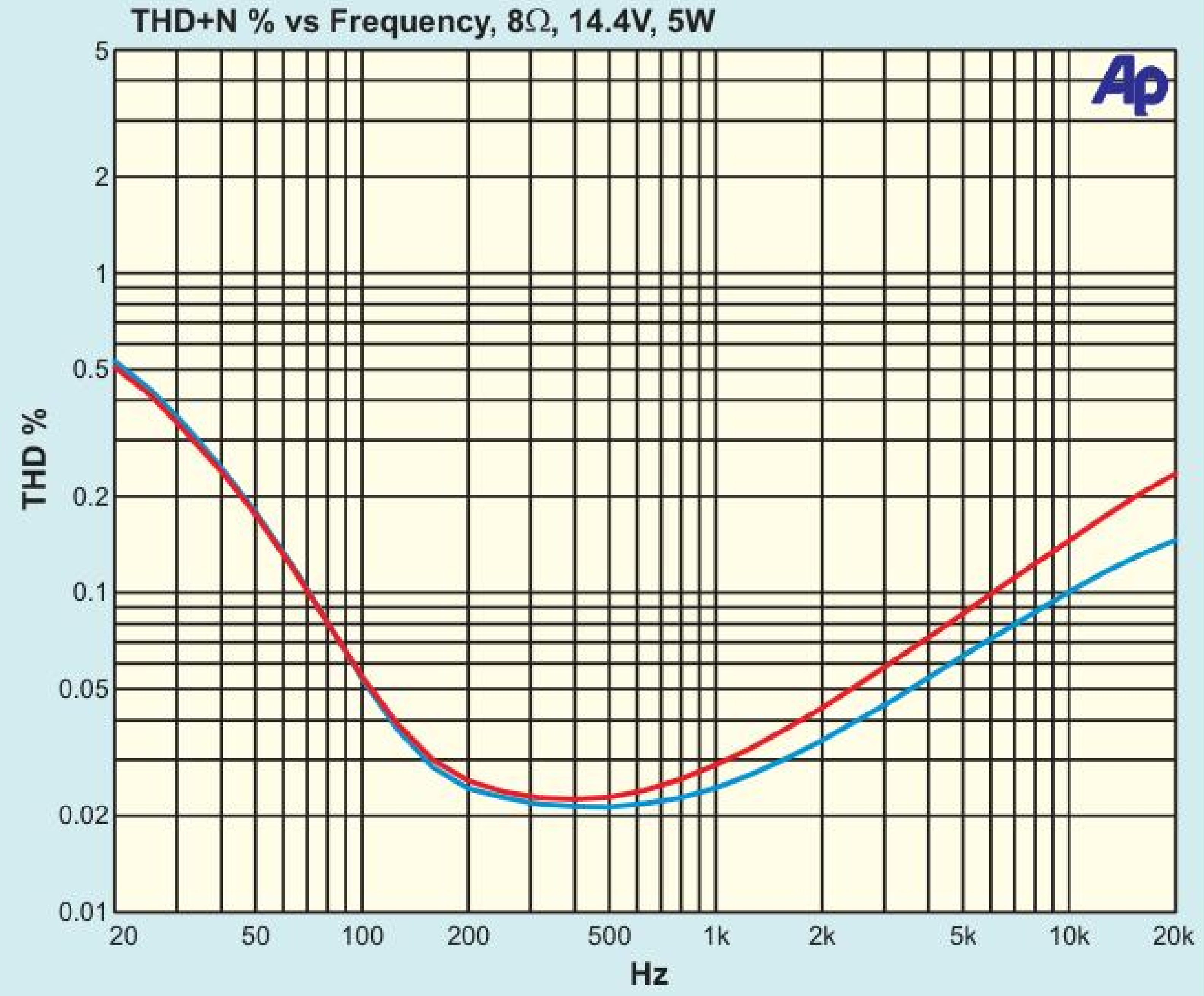


Fig.6: THD+N vs frequency for 5W into 8Ω. The supply is 14.4V and the measurement bandwidth is <10Hz-80kHz. The reading at 1kHz is slightly higher than in Fig.2 due to the wider measurement bandwidth.

Start by gently inserting its pins through the board, taking care not to bend any of them. You may need to adjust them using needle-nose pliers if they have been bent during transport, so that they line up properly.

Once the pins have been pushed all the way down, place the metal tab of the IC on a flat, horizontal surface with the PC board held in a vertical position. Hold the IC down against the surface and adjust the angle of the board so that they are exactly at right angles. That done, check that the pins are all still properly inserted and that the package is parallel with the edge of the board.

When it is all straight, solder a couple of leads and recheck its orientation before finishing the job.

The four 2200µF electrolytic capacitors can now be installed. Make sure that each of these sits flush against the PC board, and is oriented correctly.

Short cut

Before fitting the potentiometers (VR1 to VR3), it's necessary to cut their shafts to length so that the 'D'-shaped sections (ie, the flat sections) are about 10mm long. This is done by clamping the end of each shaft in a vice and then cutting it with a hacksaw. Deburr the ends when you have finished, so that the knobs can be fitted later.

Pots VR1 to VR3 can now be installed on the board. They each have a different value, so be sure to mount each one in the correct location.

Earthing

To prevent noise pickup, it's necessary to 'earth' the bodies of the pots. This is done using a length of tinned copper wire, which loops across the top of the pots and is terminated at both ends to copper pads on the PC board.

To install this wire, first solder one end to the pad immediately to the right of volume control VR1. That done, stretch the wire across the tops of the three pots and feed the free end into the pad to the left of the bass pot. Finally, pull the wire down tight and solder it in position, then solder the wire to the top of each pot body.

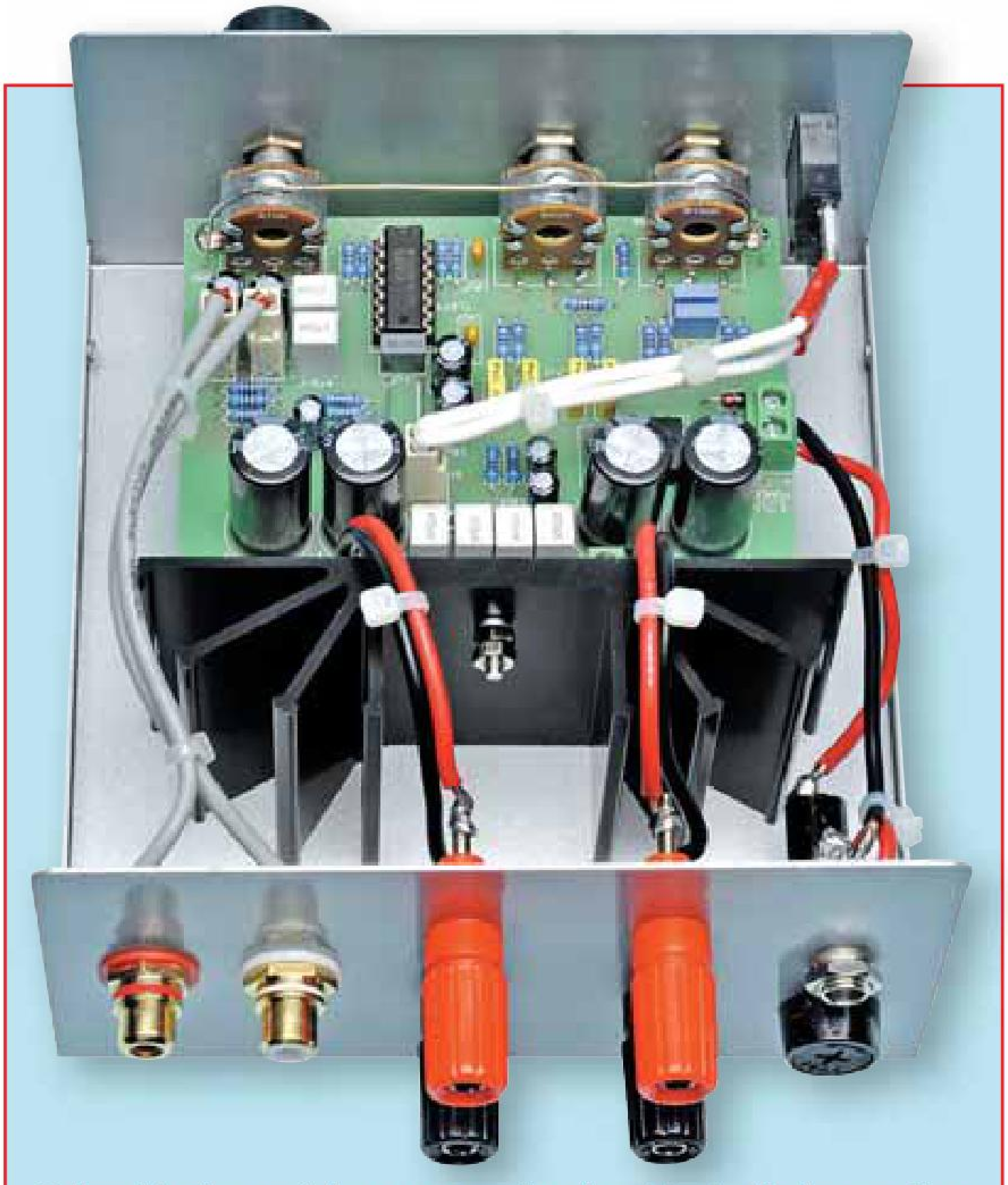
Note that it will be necessary to scrape away the passivation material on each pot body in order for the solder to take. You will also need to use a hotter-than-normal soldering iron in order to heat the pot bodies sufficiently for soldering.

In practice, the pot bodies will later all be in contact with the bare metal of the case, so it should not be necessary to connect the GND pad on the PC board to the case itself. **However, if you elect to house the board in a plastic case, it will be necessary to connect the GND pad to the ground (–) terminal of CON3.**

The PC board assembly can now be completed by attaching an M3 ×12mm

Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	5	100kΩ	brown black yellow brown	brown black black orange brown
☐	8	22kΩ	red red orange brown	red red black red brown
☐	4	10kΩ	brown black orange brown	brown black black red brown
☐	4	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	2	1kΩ	brown black red brown	brown black black brown brown
☐	4	10Ω	brown black black brown	brown black black gold brown



Follow this photo and the text to complete the wiring inside the case. Note the use of shielded cable to connect the RCA-type phono input sockets.

spacer to each corner, secured by M3 × 15mm machine screws. That done, thread M3 × 9mm spacers over each end so that you effectively finish up with four 21mm spacers. Note: the spacers at the rear of the board are later removed when it is attached to the heatsink.

Initial checks

If you have a bench supply, set it to 12V with a current limit of 200mA. Otherwise, use a 12V plugpack or similar supply – if possible, one which is too small to provide much current.

First, connect your DC supply to the power block (CON3), with a DMM wired in series and set to read current. Now switch the supply on and check the current reading. With no power switch attached, the current should be negligible (<1mA) and the DMM will probably read 0 (once the 2200μF capacitors have charged).

If it reads more than a few milliamps, switch off and check the board for mistakes.

Now short the switch header pins (ie, for S1) together using a piece of wire. The current should now increase to around 100mA and possibly as high as 160mA. If you remove this short, the reading should drop back to 0mA within a second or so.

If you have made a mistake with the MOSFET or Zeners, it's possible no current will flow at all. If that happens, check that area of the board. It could also be a problem with the standby RC filter components (22kΩ and 1μF).

Drilling the case

The drilling details for the front and rear panels of the case are shown in Fig.7. This can be photocopied and used as a template.

Start by attaching the front panel drilling template section to the case. Once that's done, centre-punch the location of each hole, then remove the template and drill a small pilot (eg, 2mm) hole at each location. Before going further, place the board assembly in the case and check that the three right-hand holes line up correctly with the centres of the pot shafts.

Once you are satisfied that everything is correct, drill the three potentiometer holes to 6.5mm, then check that their shafts (including the threaded portions) go all the way through). If necessary, enlarge the holes using a tapered reamer until it fits correctly.

The switch cutout is made by first pilot-drilling the two marked positions, then enlarging them to 5.5mm and drilling a third hole between them. The centre piece can then be knocked out and a small flat file used to gradually enlarge the cutout to the marked rectangular outline.

Slowly enlarge it in each direction until the switch snaps into place and is locked in by its plastic tabs. It will take a good 10 to 15 minutes of patient filing, so take it slowly and make sure you don't make the hole too large or crooked.

Installing the PC board

In order to later secure the PC board, it's necessary to drill mounting holes in the base of the case for the front (but not the rear) spacers. The two holes should each be marked on the underside of the case, and are positioned 6mm in from the front panel and 21mm in from the sides. Drill them to 3mm, then slide the board into position and fit the mounting screws.

Don't worry about securing the pots to the front panel at this stage – that step comes later. For the time being, just check that everything lines up correctly, then remove the board and power switch so that the rear panel can be drilled.

Rear panel drilling

Eight holes have to be drilled in the rear panel – two for the insulated RCA-type phono input sockets (D), four for the loudspeaker terminals (C), one for the DC power socket (C) and one for the fuse (E).

Begin by securing the drilling template accurately in position (use tape), then centre-punch each hole location, and drill small pilot holes. The template can then be removed and the

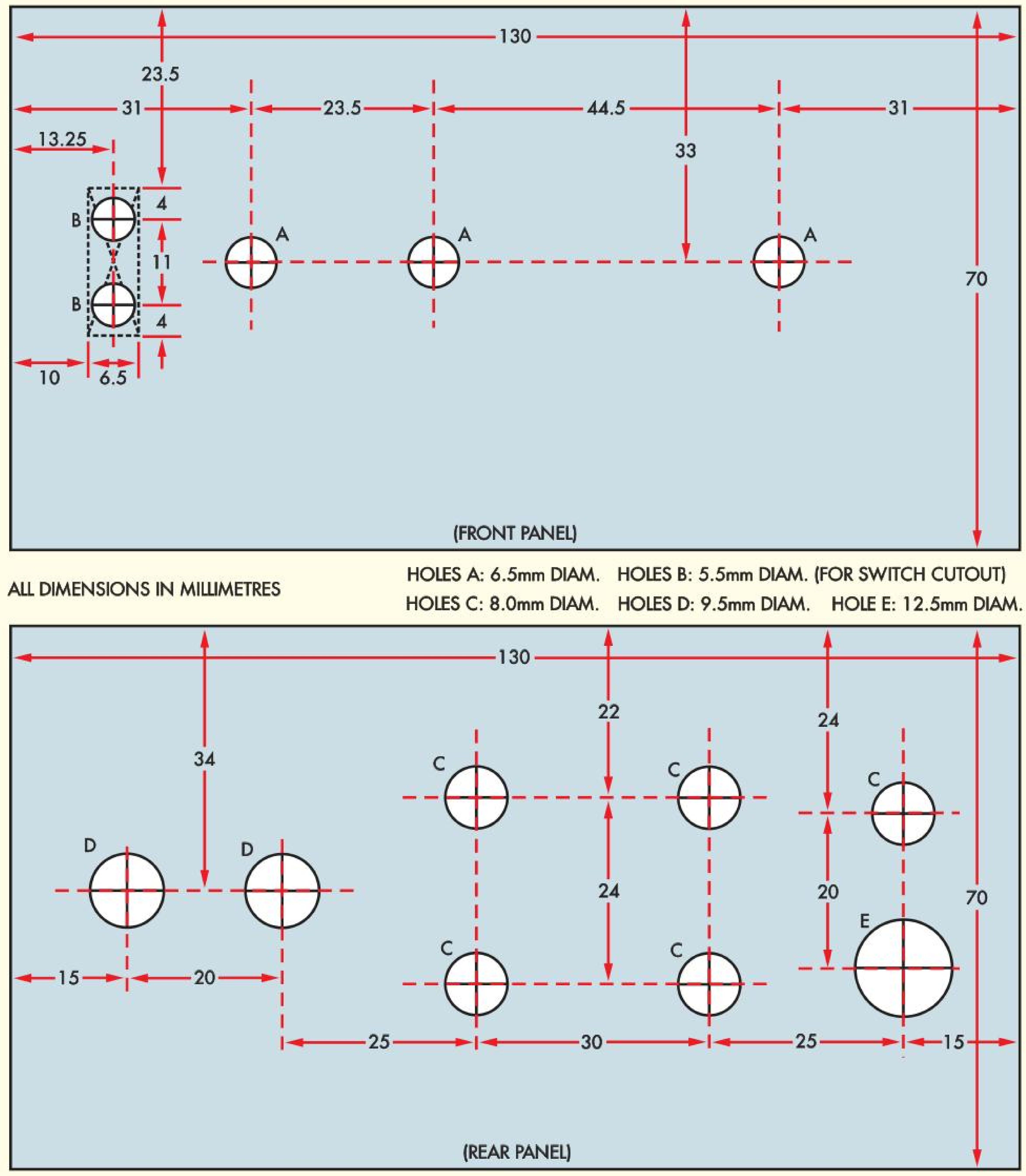

130
23.5
31
23.5
44.5
31
13.25
33
B
B
4
11
4
A
A
A
70
10
6.5
(FRONT PANEL)
ALL DIMENSIONS IN MILLIMETRES
HOLES A: 6.5mm DIAM. HOLES B: 5.5mm DIAM. (FOR SWITCH CUTOUT)
HOLES C: 8.0mm DIAM. HOLES D: 9.5mm DIAM. HOLE E: 12.5mm DIAM.
130
22
24
34
C
C
C
D
D
24
20
E
70
C
C
15
20
25
30
25
15
(REAR PANEL)

Fig.7: full-size drilling templates for the front and rear panels. Centre-punch each hole position and drill small pilot holes before carefully enlarging them to size using progressively larger drills and a tapered reamer.

holes enlarged to the sizes indicated using drills and a tapered reamer (ie, 8mm for the binding posts and DC connector, 9.5mm for the phono sockets and 13 to 15mm for the fuseholder, depending on the exact type).

Use an oversize drill to deburr the holes, then install the rear panel hardware as shown in the photos. Make sure all the nuts are tight so the components can't rotate. By the way, *insulated* RCA-type phono sockets are mandatory if you want to get low distortion.

Pay attention to the orientation of the holes in the binding posts. The upper two (red) should have the holes vertical, while the lower two (black) should be orientated with the holes 30° to 45° from vertical, so that you can insert the speaker leads from the side.

Attaching the heatsink

The specified heatsink is a 55mm × 105mm 'fan' type. It is quite heavy, so it will need to be attached to the base of the case using two right-angle steel brackets (see the photo two pages on – homemade *matching* aluminium or sheet steel will work perfectly well).

To do this, stand the heatsink vertically on a flat surface and place a bracket flush against the flat side at one end. Mark the centre of the mounting hole, then repeat this procedure at the other end. The two holes are then centre-punched and drilled to 4mm. Remove any swarf from around the holes using an oversize drill, then attach the brackets using two M4 × 10mm machine screws, spring washers and nuts.

Now remove the rear spacers from the PC board, install it in the case and slide the heatsink up to it so that it sits flush against IC2's metal tab. Check that the heatsink is correctly centred, then mark the mounting holes for the heatsink brackets on the bottom of the case. The heatsink and PC board are then removed and the marked locations drilled to 4mm.

The next step is to drill a mounting hole in the heatsink for IC2's metal tab. That's done by first reinstalling the PC board in the case and securing

Using a MOSFET as a diode

In this project we have used a MOSFET instead of a diode for reverse polarity protection, for the reasons explained in the article.

Fig.8 shows how an N-channel MOSFET is typically used for motor control, lamp flashing or any other task where a high current DC electronic switch is required. Because a MOSFET's source is generally connected to the substrate, a parasitic diode known as the 'body diode' is present. This is shown in the symbol and it cannot be avoided.

Because its source (S) is connected to ground, Q1 is on whenever the gate (G) voltage is above the MOSFET's on-threshold (usually 2V to 4V). The body diode is reverse biased and does not conduct unless the load is inductive and switch-off causes a large enough positive voltage spike to trigger reverse breakdown (avalanche).

What we want to do, though, is use a MOSFET to prevent current flow if V_{CC} becomes negative. In the case of Fig.8, if this were to happen, the body diode would conduct and it would be impossible for the MOSFET to provide reverse polarity protection. Hence, we must reverse the MOSFET and connect it so that the source is positive with respect to the drain (D), as shown in Fig.9.

Note that the body diode is now forward biased when V_{CC} is positive. If we also bias the MOSFET on, all of the current will flow through the channel (ie, source to drain) instead. The channel path will have a much lower voltage drop than the body diode.

We achieve this by connecting a resistor between the supply input and the gate. When the supply voltage is positive, the MOSFET is turned on and if it becomes negative it will be turned off and of course, the body diode will be reverse-biased!

Because the source is no longer connected to ground it may seem that we can no longer turn the MOSFET on. In fact, the source is pulled to ground via the body diode.

The final refinement adds two back-to-back Zener diodes between the gate and source terminals (see Fig.3). They are included to prevent a supply voltage spike of more than ±20V destroying the MOSFET.

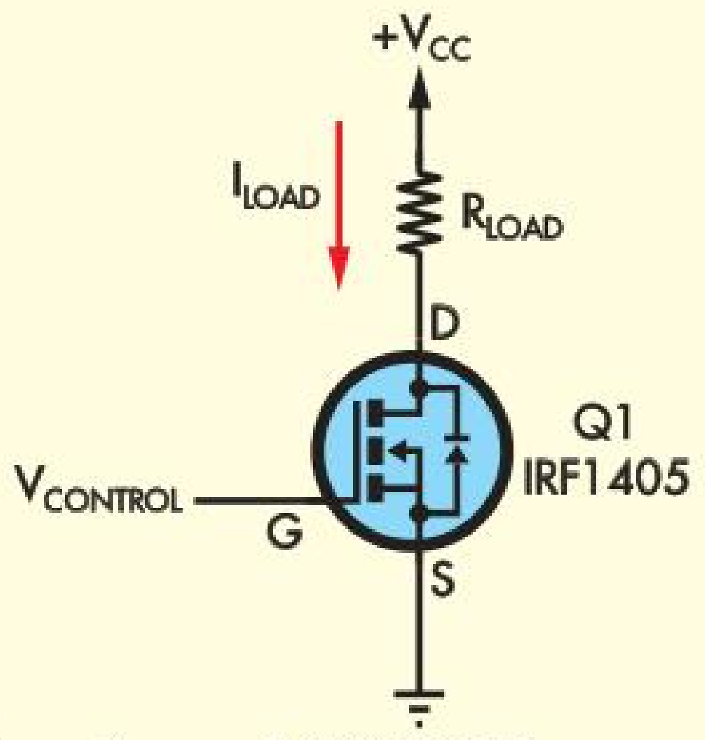


Fig.8: using a MOSFET as a switch (typical connection).

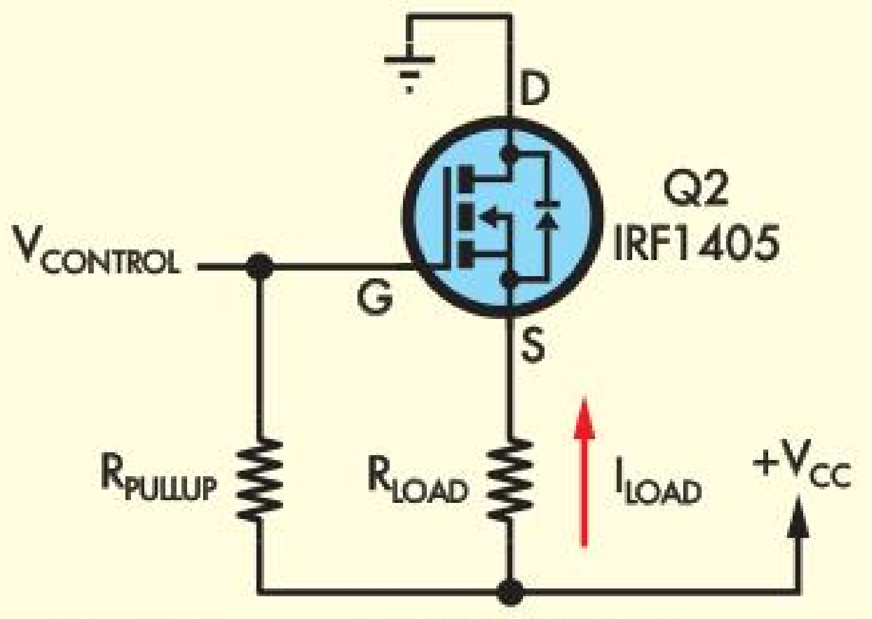


Fig.9: using a MOSFET as an active rectifier.

the heatsink to the base using two M4 × 10mm machine screws and nuts. It's then just a matter of marking the hole location, then removing the heatsink, centre-punching the marked location and drilling to 3mm.

Now use an oversize drill to carefully deburr the mounting hole. **This step is most important – if there's any metal swarf around the hole, it could punch through the insulating washer that's used to electrically isolate IC2's tab from the heatsink and create a short circuit.** Basically, it's just a matter of checking that the mounting area is perfectly smooth by running your finger over the hole.

Attaching IC2 to the heatsink

IC2's tab must be electrically isolated from the heatsink using an insulating bush and washer – see Fig.10. It's just a matter of fitting the heatsink back in the chassis, then attaching IC2's tab as shown. It's secured using an M3 × 15mm machine screw, spring washer and nut. Do the screw up firmly to ensure good thermal contact, then use your multimeter (set to a low ohms range) to confirm that IC2's tab is correctly isolated from the heatsink.

If you use a mica washer rather than a thermal insulating pad, be sure to smear both sides of the washer with thermal grease before bolting the tab down.

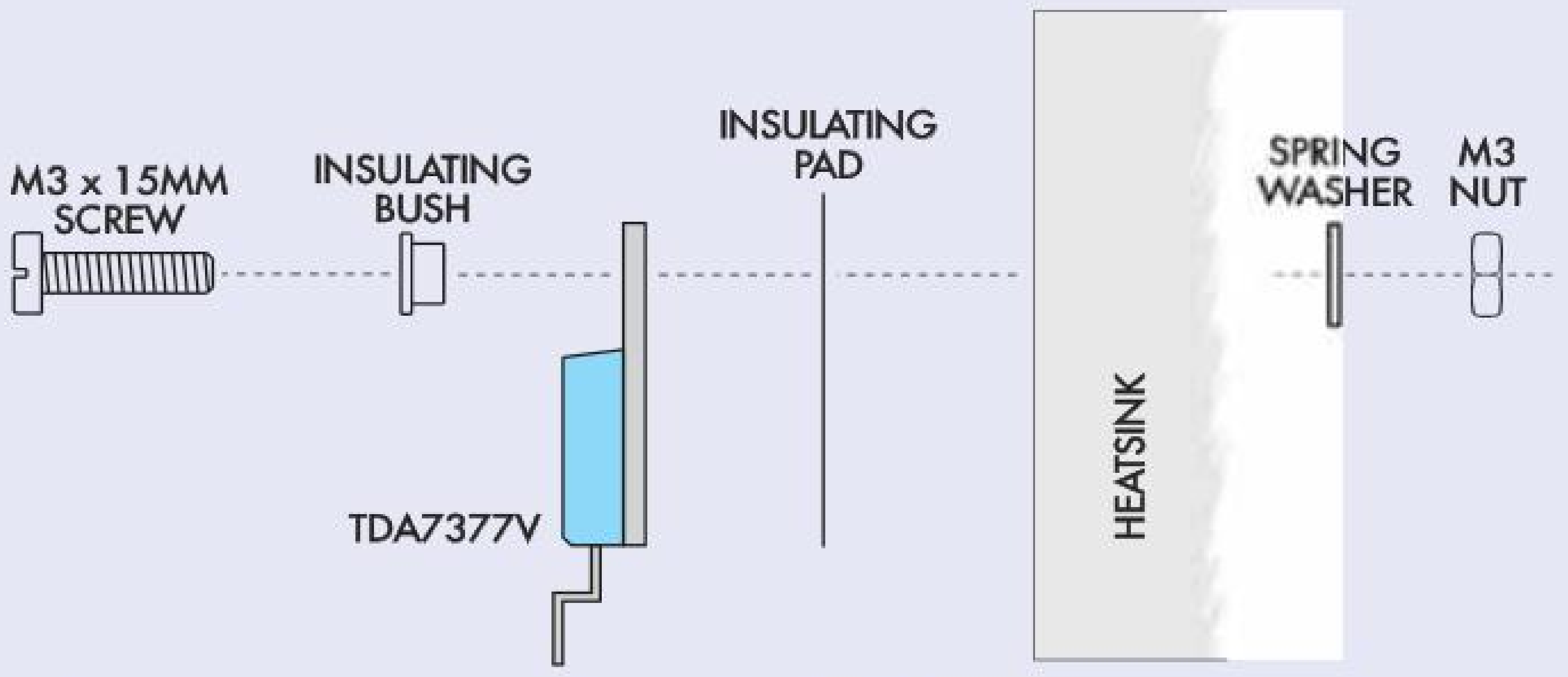


Fig.10: this diagram shows how the TDA7377V amplifier IC is attached to the heatsink. It must be electrically isolated from the heatsink using an insulating bush and pad.

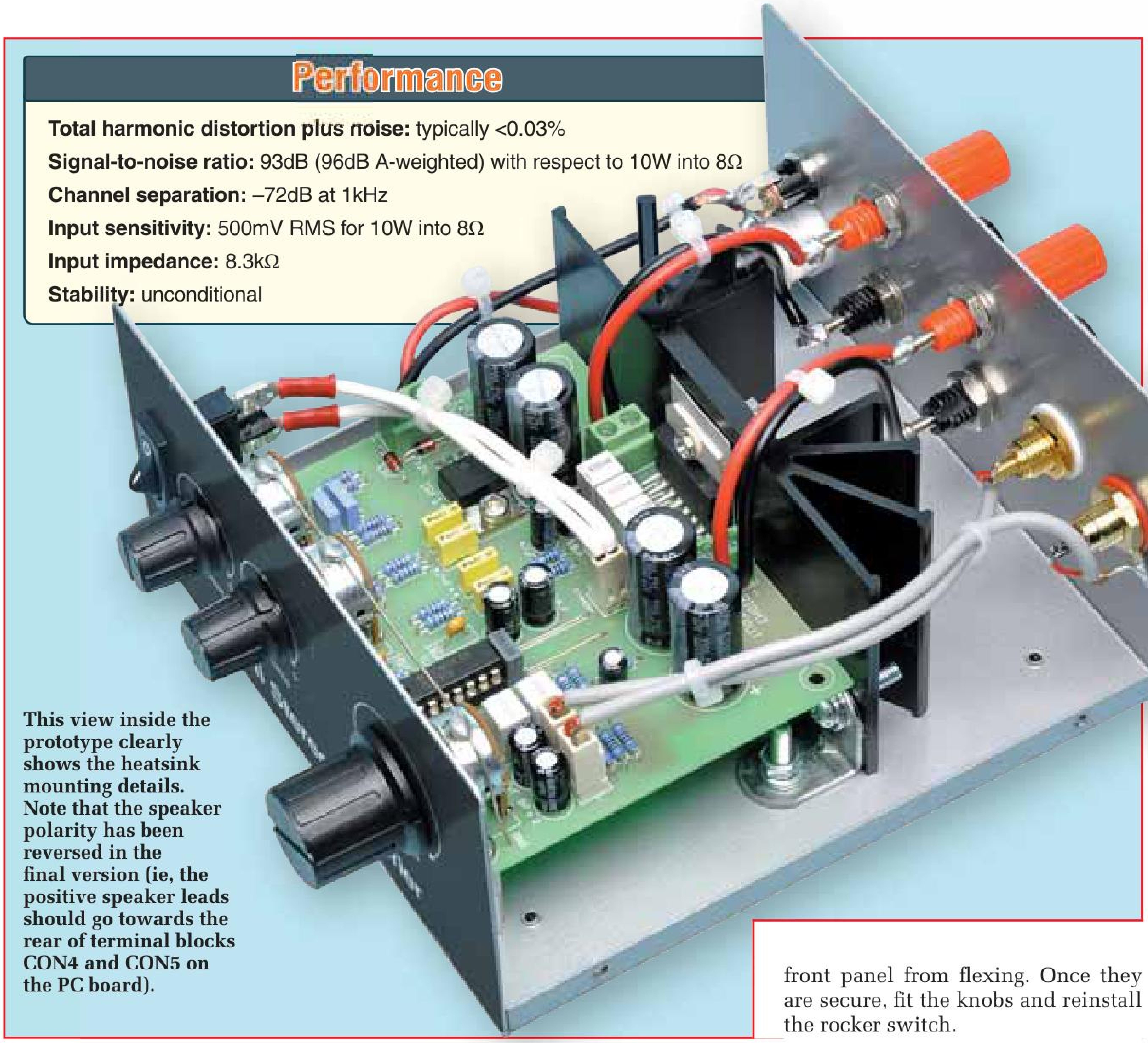
Front panel

A full-size, suggested front panel design is given in Fig.11. This can be photocopied, trimmed and attached to the panel using double-sided tape. This should be done with the PC board and heatsink assembly removed from the case. You will also have to temporarily remove the rocker switch if it's in place.

Once the front panel is in position, cover it with some wide strips of adhesive tape, then cut out the holes for the switch and pot shafts using a sharp knife. The adhesive covering will protect the label from scratches and finger marks and provide a durable finish.

The PC board and heatsink assembly can now be permanently installed in the chassis. Before sliding it in, fit a nut onto the threaded boss of each pot and wind it all the way up to the pot body. That done, place the assembly in the case and secure it via the heatsink brackets and the screws that go into the front spacers.

Now wind the pot nuts forward until they contact the rear of the front panel, then fit three more nuts to the pots from the front. The six pot nuts can now all be tightened to lock the pots firmly in place and prevent the



Performance

Total harmonic distortion plus noise: typically <0.03%
Signal-to-noise ratio: 93dB (96dB A-weighted) with respect to 10W into 8Ω
Channel separation: –72dB at 1kHz
Input sensitivity: 500mV RMS for 10W into 8Ω
Input impedance: 8.3kΩ
Stability: unconditional

This view inside the prototype clearly shows the heatsink mounting details. Note that the speaker polarity has been reversed in the final version (ie, the positive speaker leads should go towards the rear of terminal blocks CON4 and CON5 on the PC board).

front panel from flexing. Once they are secure, fit the knobs and reinstall the rocker switch.

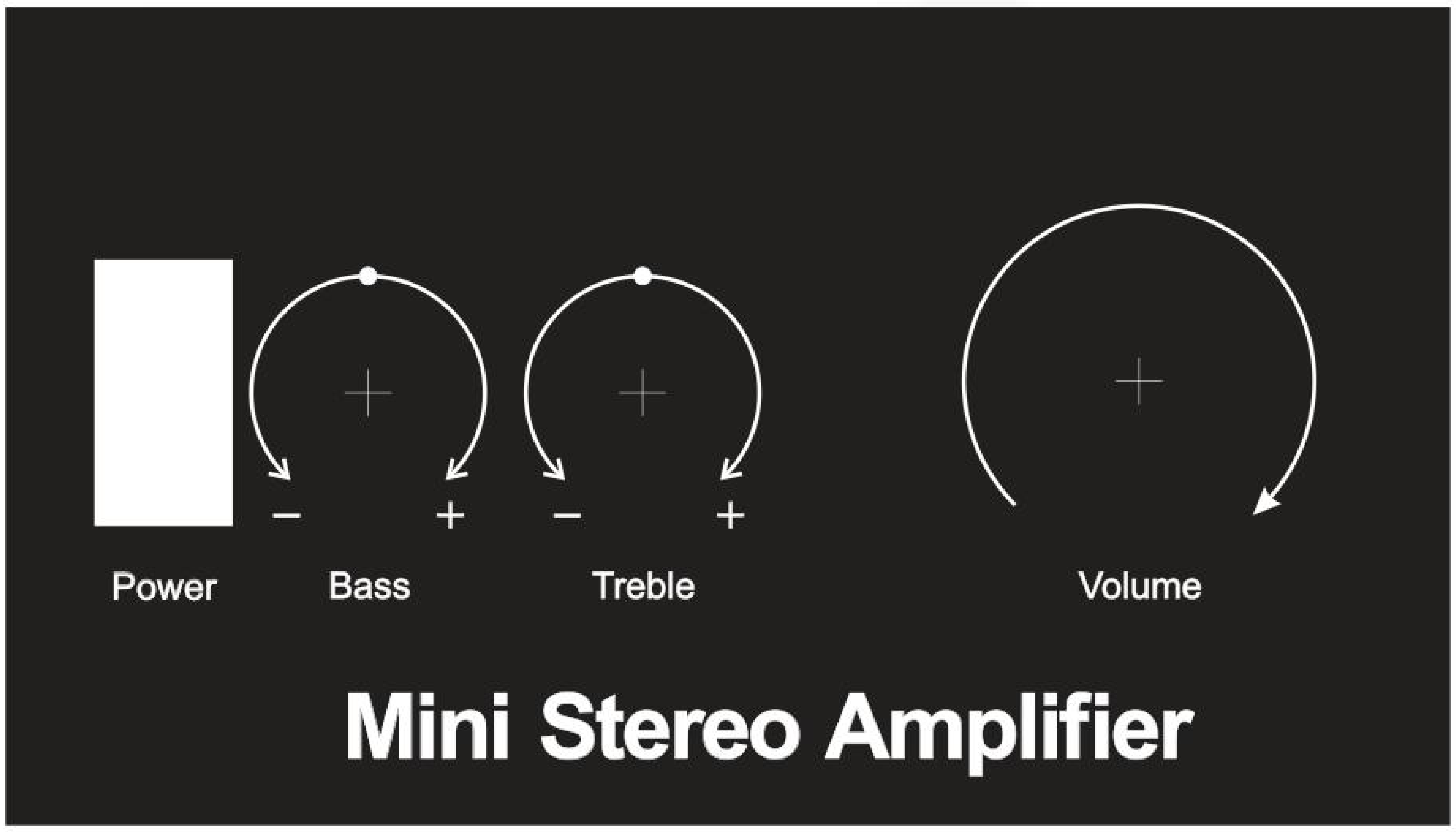


Fig.11: Full-size front facia and lettering. This can be photocopied and attached to the front panel using double-sided tape

Chassis wiring

All that's left is the chassis wiring. First, cut a short length of red, heavy-duty hook-up wire, strip the ends and solder it between the centre pin of the DC socket and the middle tab of the fuseholder. A 70mm length of red wire is then run from the end fuseholder tab to the +12V input terminal on the board (ie, at CON3).

Now connect the two remaining tabs on the DC socket together and run a 90mm length of black heavy-duty wire to the ground (–) terminal of CON3. In fact, the easiest way to do this is to strip the insulation from the hook-up wire back at least 15mm and wrap the wire around both these tabs before flowing solder over it. Because one of the tabs goes

Parts List – High-Performance 12V Stereo Amplifier

- 1 PC board, code 843, available from the *EPE PCB Service,* size 97mm × 78mm
- 1 vented aluminium case (Jaycar HB-5444)
- 1 55mm ‘fan’- type heatsink (Jaycar HH-8570)
- 1 SPST mini rocker switch (Jaycar SK-0975)
- 2 4.8mm female spade lugs
- 2 small steel brackets (steel or aluminium)
- 4 M4 × 10mm machine screws
- 4 M4 nuts
- 4 M4 spring washers
- 1 2.1mm ID chassis-mount DC power socket (Jaycar PS-0522)
- 1 low-voltage M205 chassis-mount fuseholder (Jaycar SZ-2020)
- 1 M205 6.5A fast-blow fuse
- 2 red insulated binding posts (Jaycar PT-0453)
- 2 black insulated binding posts (Jaycar PT-0454)
- 1 red insulated RCA-type phono socket (Jaycar PS-0276)
- 1 white insulated RCA-type phono socket (Jaycar PS-0278)
- 2 16mm knobs (Jaycar HK-7762)
- 1 24mm knob (Jaycar HK-7764)
- 3 2-pin terminal blocks (5.08mm spacing)
- 3 2-pin polarised headers (2.54mm spacing)
- 3 2-pin polarised header connectors (2.54mm spacing)
- 1 TO-218 mica or silicone insulating washer (with bush)
- 5 M3 × 6mm machine screws
- 1 M3 × 10mm machine screw
- 4 M3 × 15mm machine screws
- 2 M3 spring washers
- 2 M3 nuts
- 4 M3 × 12mm tapped nylon spacers
- 4 M3 × 9mm tapped nylon spacers
- 1 500mm length of red heavy-duty hook-up wire
- 1 500mm length of black heavy-duty hook-up wire
- 1 300mm length of medium-duty hook-up wire
- 1 400mm length of single-core shielded cable
- 1 300mm length of 0.71mm tinned copper wire
- Heatsink compound (if using a mica insulating washer)
- 8 100mm cable ties
- 3 additional nuts for pots

Potentiometers

- 1 100kΩ linear dual-gang 16mm potentiometer (VR2 – B100k)
- 1 50kΩ linear dual-gang 16mm potentiometer (VR3 – B50k)
- 1 10kΩ log dual-gang 16mm potentiometer (VR1 – A10k)

Semiconductors

- 1 TL074 quad op amp (IC1)
- 1 TDA7377V quad power amplifier (IC2) (available from: **www.littlediode.com**)
- 1 IRF1405 MOSFET (Q1)
- 2 15V 1W Zener diodes (ZD1,ZD2)
- 1 1N4004 rect. diode (D1)

Capacitors

- 4 2200µF 25V electrolytic
- 1 100µF 25V electrolytic
- 2 47µF 16V electrolytic
- 4 4.7µF non-polar (NP) electrolytic
- 1 1µF 25V electrolytic
- 6 470nF MKT
- 1 100nF MKT
- 2 10nF MKT
- 4 4.7nF MKT
- 2 10pF ceramic

Resistors (0.25W, 1%)

- 5 100kΩ
- 8 22kΩ
- 4 10kΩ
- 4 4.7kΩ
- 2 1kΩ
- 4 10Ω

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to the metal thread of the DC socket, this connects the negative rail to the case and improves the shielding.

Next, connect the speaker outputs, again using heavy-duty red and black hook-up wire (see photos). These leads run from CON4 and CON5 to the binding post terminals on the rear panel and should be made long enough so that they don’t touch the heatsink.

Note that we’ve reversed the output terminal polarity compared to our prototype to compensate for the inverting preamplifier stage. Ultimately, though, it doesn’t matter greatly, as long as both pairs of binding posts are connected the same way around (ie, the loudspeakers are not in anti-phase with each other).

The power switch wiring is next. This can be run using two 95mm lengths of medium-duty hook-up wire. Begin by stripping about 8mm from one end of each wire and crimping them to two polarised header pins using pliers. Once you have crimped them, flow some solder into each junction so that it can’t come apart.

After soldering, insert the two pins into one of the plastic header blocks then strip about 5mm from the other ends of the wires. These ends are then attached to 4.8mm female spade connectors (a ratcheting crimper will do the best job) which are then pushed onto the switch terminals.

Alternatively, solder the wires directly to the switch terminals if that’s what you prefer – be careful not to overheat and damage the plastic switch body.

Wiring the phono sockets

All that remains is the wiring to the RCA-type input sockets. These are connected using two lengths of shielded/screened cable, which run back to two polarised pin headers situated behind the volume control.

Begin by cutting two 150mm sections of shielded cable, strip 20mm of insulation from each end and twist the copper screening braid wires together. Then strip 5mm of insulation from the inner wires.

At one end, tin the shield and inner wires, then crimp them into polarised header pins and flow solder into the crimp pin so it can’t come apart. Note that it’s necessary to twist the shield wires tightly before soldering them, so that they fit into the header pins.

After soldering, insert the pins into the two remaining plastic header blocks. In each case, the inner wire of the shielded cable must go to the ‘+’ side of the header block (see Fig.4). This means that when the headers are plugged in, the inner wire of each header must be to the left, as viewed from the front of the PC board.

The shield leads must be to the right, so that they connect to the earth pattern of the PC board when the headers are plugged in.

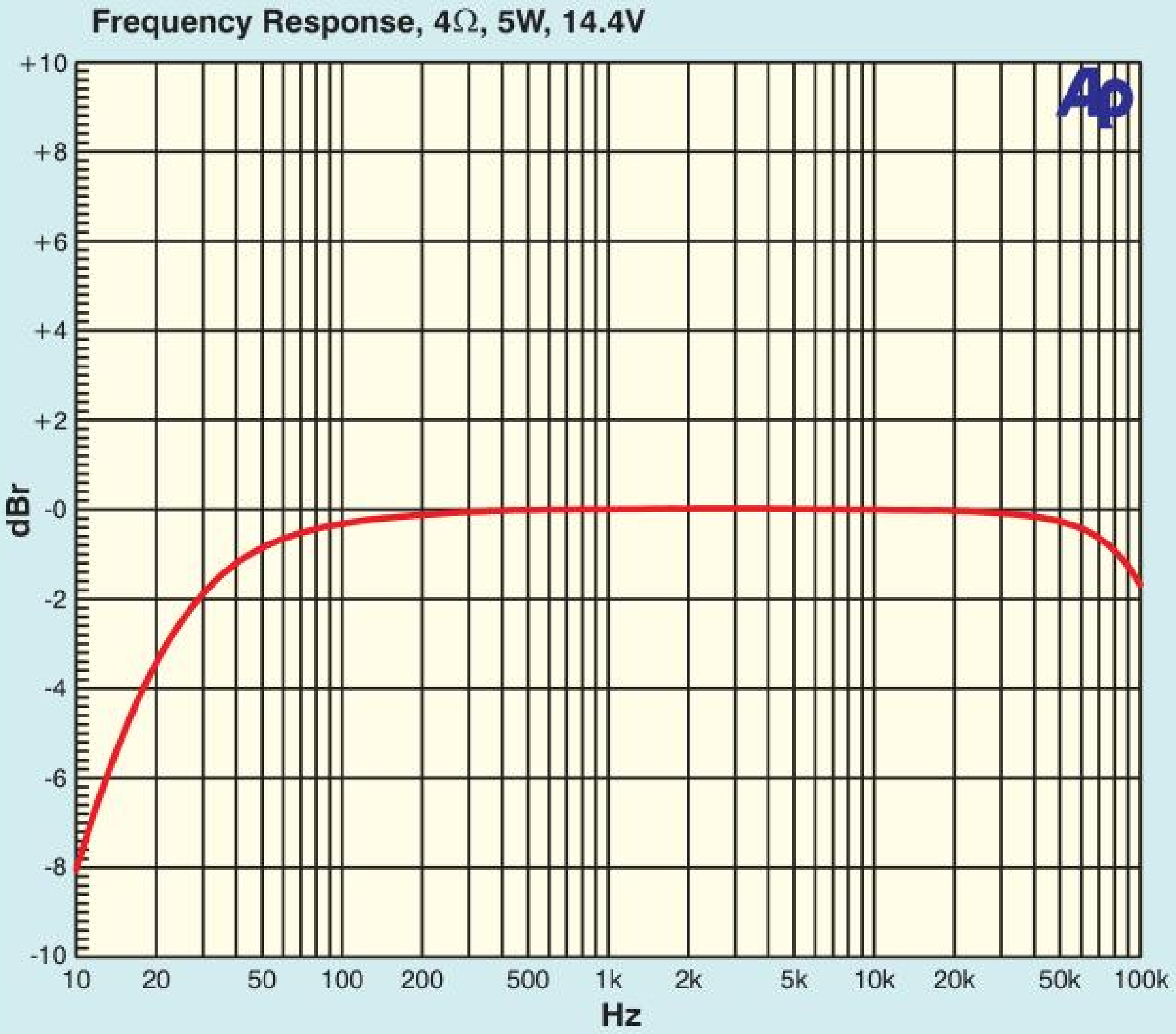

Fig.12: this shows the amplifier's frequency response for a 4Ω load with the tone controls centred. The –3dB point is around 25Hz. This is purposefully a little high to reduce the chance of 'motor-boating' with a sagging supply voltage under load.

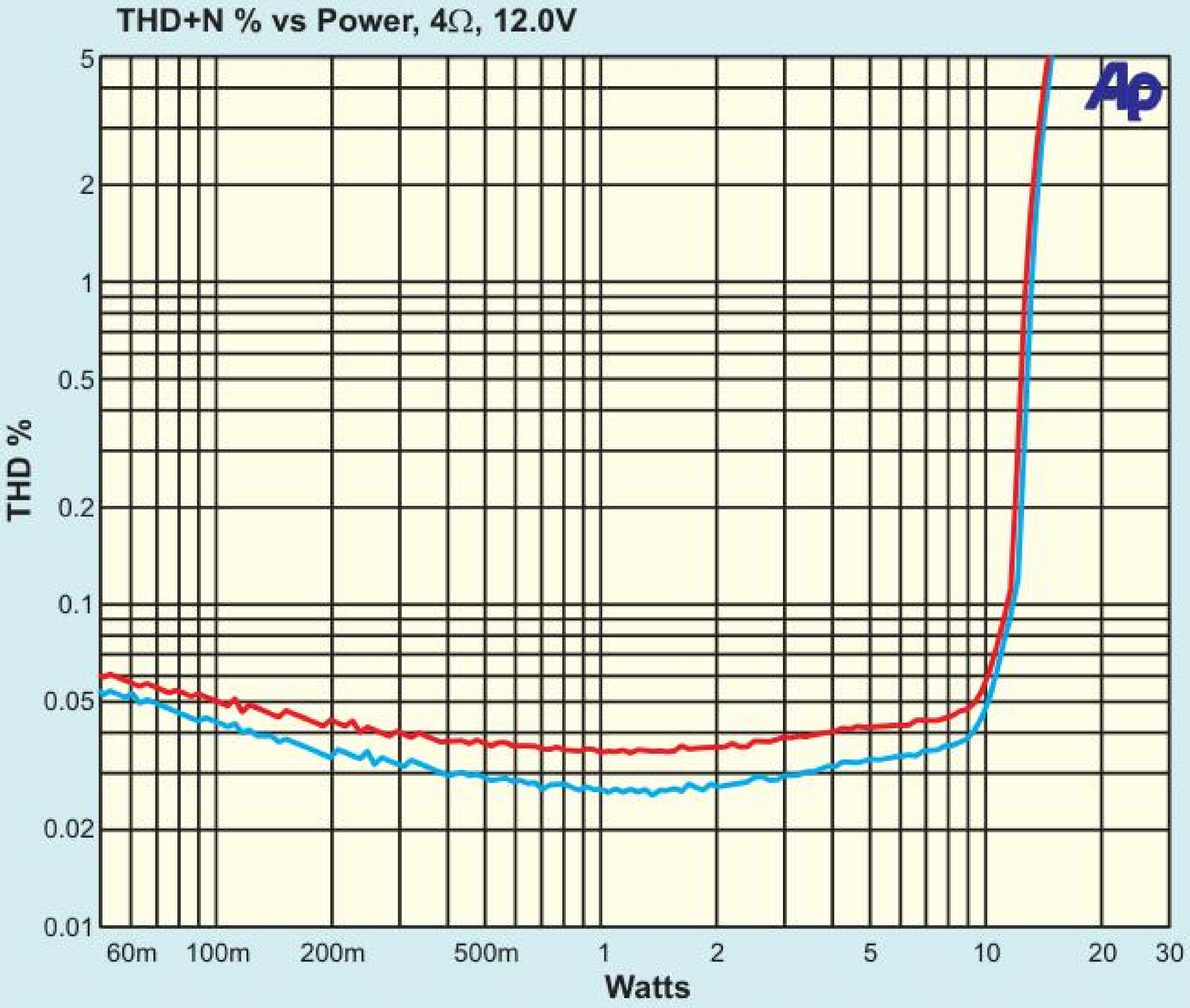

Fig.13: this graph of THD+N vs power is similar to that shown in Fig.1, except that the amplifier is powered from a 12V 4A switchmode supply. As you can see, performance doesn't suffer much, except that full power output is reduced due to the lower supply voltage.

Connecting the GND terminal

If you build the unit into the specified metal case, then it will not be necessary to connect the GND terminal to the case. That's because the circuit earth is connected to the case via the DC power socket, while the potentiometer bodies are earthed to the case via the nuts used to secure them.

In fact, if you do connect the GND pad to the case under these circumstances, you could get an 'earth loop'.

Conversely, if you elect to house the board in a plastic case, then it will be necessary to connect the GND pad to the ground (–) terminal of CON3. Alternatively, it can be connected to the negative terminal of the DC socket.

Similarly, if the pots are not directly secured to a metal chassis (ie, you don't fit the nuts), then the GND terminal should be connected to metalwork. You can do this by securing a solder lug to the base of the case and then running a short lead between it and the GND pad on the board.

The other ends of the shielded leads can then be soldered to the RCA phono sockets. In each case, the inner lead goes to the centre terminal of the socket, while the shield wire is soldered to the solder tag.

As stated above, it's necessary to use insulated phono sockets for the inputs. After connecting them, it's a good idea to check that neither phono socket surround is shorted to the case (if they are, the performance will suffer). You can do this by using your multimeter to check for continuity between the outside metal surround of each phono socket and the case. You should get an open circuit reading for both sockets.

If the meter does indicate a short, check that the shield wires are not touching the case at the metal tags. If they are, just bend the tags forward slightly until the short is cleared.

The assembly can now be completed by plugging the other ends of the shielded leads into the headers on the PC board. Don't get them mixed up – the left input (white socket) should go to the header on the left side of the PC board, and vice versa.

Once the wiring is complete, use some cable ties to secure the various leads as shown in the photos. This not only keeps them looking tidy but will also prevent them from coming adrift.

That's it – construction is complete.

Final testing

Now for a final test. Install the 6.5A fuse into the fuseholder and connect a signal source (eg, a CD player) and a pair of speakers. Be sure to connect the speakers in phase and don't cross-wire the leads.

Now turn the volume knob all the way down, switch on and slowly turn the volume up. If you hear audio loud and clear then all is well! If not, switch off immediately and check the chassis wiring carefully. If there's a problem, it's a good idea to first measure the voltage across the power terminal block, to make sure power is actually reaching the board.

If that doesn't solve the problem, you'll need to recheck the component placement and orientation, as well as the solder joints. If the fuse blows, then you likely have a short circuit in your chassis wiring, because the earlier tests on the board would have shown up any shorts on the board itself.

Assuming all is well, put on your favourite CD and enjoy the sound! ***EPE***

TechnoTalk

Statistics

Mark Nelson

That's statistics, as in 'lies, damned lies and statistics'. But how can you argue with figures? Mark doesn't even try, as they tell an interesting story.

ACCORDING to network equipment provider Cisco, the number of network-connected devices will exceed the number of people on earth in 2016. In that year, the world population will reach 7.3 billion, but the number of mobile Internet-connected devices will rise above 10 billion. During 2011 to 2016, Cisco anticipates that global mobile data traffic will outgrow global fixed data traffic by three times.

But how will this be, and why? The expected sharp increase in mobile traffic is due, in part, to a projected surge in the number of mobile Internet-connected devices, including machine-to-machine (M2M) modules. A major new market, says Cisco, is the use of wireless networks to update digital billboards. This will allow advertisers to display different messages based on time of day or day-of-week, and allow quick global changes for messages, such as price changes for petrol.

Two things are driving this growth. Mobile devices are becoming more powerful, and are thus able to consume and generate more data traffic. At the same time, users now prefer streamed content rather than simple downloads. So, mobile traffic will increase, growing 28-fold from 2011 to 2016, a compound annual growth rate of 95 per cent. Let's leave this remarkable forecast with a quote from Suraj Shetty, vice president of product and solutions marketing at Cisco. 'By 2016, 60 per cent of mobile users – three billion people worldwide – will belong to the 'Gigabyte Club', each generating more than one gigabyte of mobile data traffic per month. By contrast, only one-half per cent of mobile users qualified last year.'

Milestone moment?

More numerical proof of rapid change comes from audience research body RAJAR. Radio listening from digital platforms (DAB radio, Freeview and Internet radio) now stands at 29 per cent of all radio listening, while more than 40 per cent of people (21 million adults) live in a household with a DAB digital radio. At the same time, 15 per cent of adults aged 15-plus listened to the radio via mobile phone.

What makes this growth all the more remarkable is the depressing audio quality of DAB radio. Don't get me wrong; I'm a DAB enthusiast, with three DAB sets in the home, but the patchy reception, strangled sound quality and frequent signal drop-out make DAB totally unsuitable for serious listening, or indeed for replacing the existing FM broadcasts. As blogger Lee Jordan sums up, 'the DAB Digital Radio platform simply isn't fit for purpose to replace existing analogue programmes, and FM remains the mainstay of radio in the UK.'

Everything is wrong with DAB, he argues. The underlying idea is good, but the execution is shocking. In most cases, the sound quality and signal strength are worse than FM. Elsewhere in the world, a far superior implementation of digital radio called DAB+ (DAB Plus) is being rolled out, but the UK government is sticking doggedly to the original version of DAB, condemning listeners to vastly degraded enjoyment.

Wanted yesterday?

Maplin Electronics can now get your purchase to you within 90 minutes; unbelievable, but true. Trade journal *Internet Retailing* reports that Maplin has signed up with delivery service Shutl to send buyers in a qualifying postcode area their plunder either within 90 minutes, or in a convenient one-hour slot of their choosing, when they check out their purchases on the Maplin site.

Shutl says more than 60 per cent of the UK's online shoppers will be able to opt for the delivery method immediately. Initially, Shutl will deliver using stock from 83 Maplin stores across the UK, adding another 21 shops later this year.

Energetic activity

There's no sign of 'energy harvesting' running out of energy if developments are anything to go by. A novel energy-harvesting evaluation kit features wireless-linked modules powered by sunlight and temperature differences.

Called 'The Drop', and costing 199 euros, it is supplied by Arrow Electronics Europe. For this price, you get three network nodes, a solar panel, a Peltier cell, three RF antennas and a mini USB cable, with which you can set up your own energy-harvesting evaluation system. You can also create your own designs based on the kit using the original schematics, Gerber files and firmware. More details at the website: **www.thedrop.eu**.

Meanwhile, a UK company has developed a power supply, the QTD20, which makes use of kinetic energy produced by AC electric motors to safeguard programmable logic controllers. In the event of a mains failure, the device utilises the power from the DC-bus capacitors, which are charged from the kinetic energy of the motor, to support the PLC until the motor has come to a complete stop, keeping the control gear and other important peripheral equipment operational long enough for a controlled shutdown to take place.

You could not make this up!

Taking the biscuit, however, is a scheme dreamed up at Purdue University, Indiana (US), in which the driving bass rhythm of rap music powers a new type of body implant. Acoustic waves from music, particularly rap, were found to recharge the pressure sensor effectively. The idea is that devices like this might one day help to treat people stricken with aneurisms (potential blood leaks) or incontinence due to paralysis.

The heart of the sensor is a vibrating cantilever, a thin beam attached at one end like a miniature diving board. Music within a certain range of frequencies, from 200Hz to 500Hz, causes the cantilever to vibrate, generating electricity and storing charge in a capacitor, says Prof Babak Ziaie. He explains: 'The music reaches the correct frequency only at certain times, for example, when there is a strong bass component. The acoustic energy from the music can pass through body tissue, causing the cantilever to vibrate.'

When the frequency falls outside of the proper range, the cantilever stops vibrating, automatically sending the electrical charge to the sensor, which takes a pressure reading and transmits data as radio signals. Because the frequency is continually changing according to the rhythm of a musical composition, the sensor can be induced to repeatedly alternate intervals of storing charge and transmitting data. 'You would only need to do this for a couple of minutes every hour or so to monitor either blood pressure or the strain of urine in the bladder,' concludes Ziaie. 'It doesn't take long to do the measurement.'

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Spiratronics

High-Quality Digital Audio Signal Generator – Part 3

In the March and April 2012 issues, we described the design and construction of our new Digital Audio Signal Generator. The final article this month has the driving instructions.

By NICHOLAS VINEN

POWER
9V DC
1000Hz - 0dB
180° - 0dB
R MUTE
L MUTE

DRIVING the Digital Audio Signal Generator is straightforward. In operation, it delivers an output signal (analogue and/or digital, depending on the configuration) as soon as it is switched on, and the LCD initially shows the current signal generation mode. There are five such readouts, one for each mode: locked, independent, mixed, pulsed and sweep.

In each case, the Up and Down buttons change the current mode and the display adjusts to show the corresponding reading. Pressing the Select button (in the centre of the main cluster) switches the LCD from the signal generation mode readout to the setting readouts. When this is done, signal generation continues according to the last mode selected.

Changing the setting readout (done using the Up and Down buttons) has no affect on the current signal generation mode. There are seven different setting readouts. Pressing the Select button again returns the unit to the signal generation mode readout.

In other words, the Select button toggles between the current signal generation mode readout and the setting readout. The active generation mode is always the mode which was last selected.

Left and right buttons

On most readouts, the left and right buttons allow you to move a cursor across the display. The only exception is the Status readout, where these two buttons have other effects (more on this later). In practice, the cursor can only move to locations which show values that can be adjusted or activated.

When the cursor is visible, pressing the Up and Down buttons will modify the indicated setting rather than changing the current readout. Pressing the Select button or moving the cursor past the first or last setting hides the cursor, and the Up and Down buttons can once again be used to change the current mode and/or readout.

This system may sound complicated, but once you try it, it will quickly start to make sense. In other words, it sounds more complicated that it really is and the process is quite intuitive once you understand the basics.

The mute buttons

There are two additional buttons on the unit – Left Mute and Right Mute. Pressing them toggles the mute status of the corresponding channel at any time. For example, if you press the Left Mute button and the left channel is currently enabled, it will be disabled and vice versa.

The mute status is shown on the status readout and also on each mode readout. For sweep mode, if a channel is muted, an 'l' (indicating the left channel) and/or an 'r' (indicating the right channel) is shown at the top of the display. For the other four modes, a muted channel is shown by changing the minus sign in front of each amplitude setting to an underscore.

If you press the two Mute buttons simultaneously, the left and right channel settings will be swapped. This includes frequency, amplitude and phase (when applicable), as well as the mute status.

Table 1 shows what each generation mode readout looks like by default, and highlights all the settings that can be changed. There is also a description of the function for each setting.

More mode information

As stated in the original article, the output frequency can be set at up to half the sample rate (ie, 48kHz) in steps of 1Hz. Depending on which frequency digit you select with the cursor, pressing the Up and Down buttons will add or subtract 1Hz, 10Hz, 100Hz, 1000Hz or 10,000Hz.

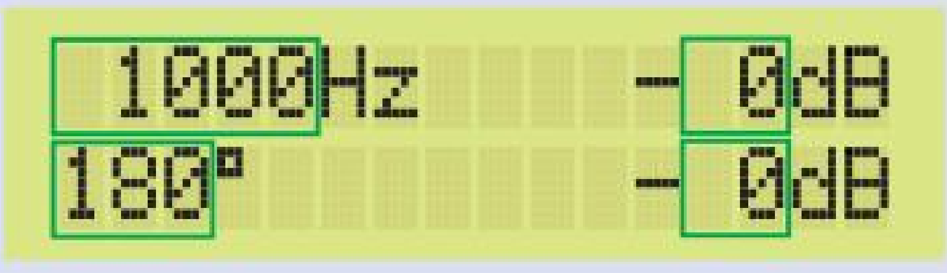
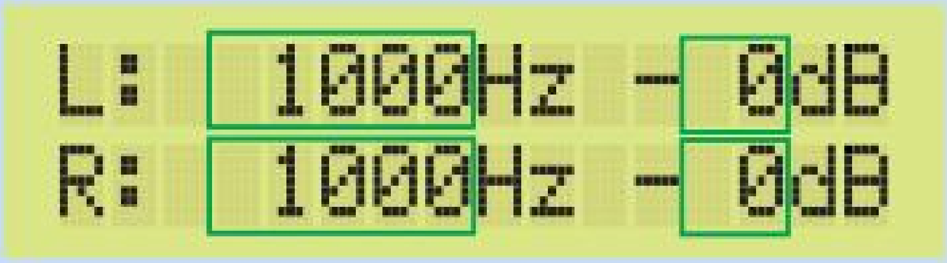
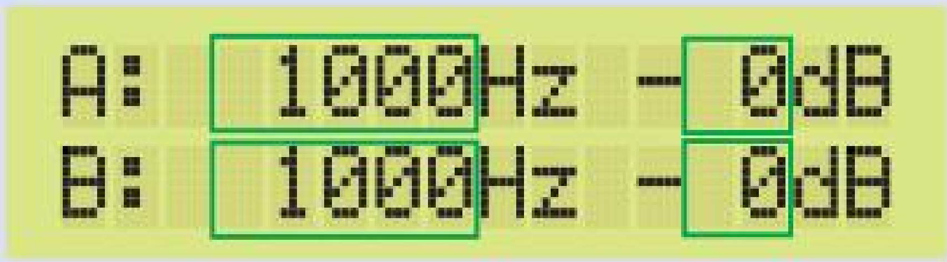
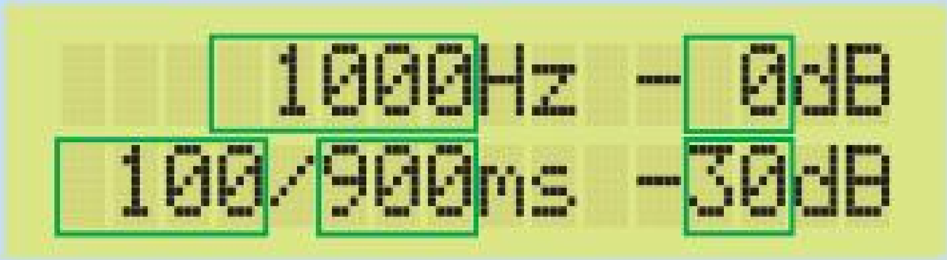
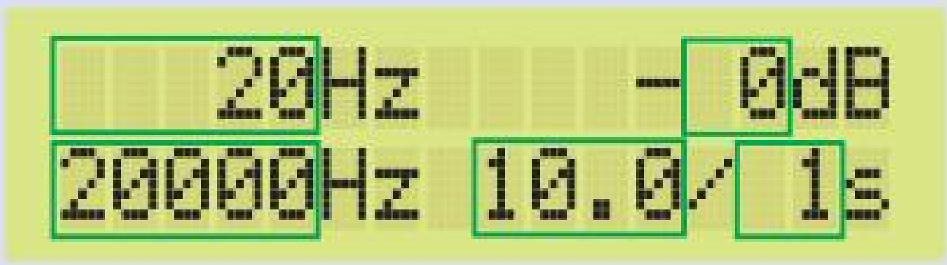
The amplitude is set in similar fashion, and the range is from 0dB to –98dB in 1dB steps.

If you increase the attenuation past –98dB, the readout changes to 'off' and the signal is muted.

Note that as you get close to –98dB, the actual signal amplitudes become so small that the error increases and some values have an identical result. In fact, –96dB, –97dB and –98dB generate the same amplitude due to the 16-bit precision of the scaling factor. However, for attenuation down to –60dB, the scaling is basically perfect. Beyond that, the measured values are as shown in Table 2.

Note that these measurements also include scaling errors from the DAC itself, so they are only a guide as to the unit's actual precision.

Table 1: Signal generation mode readouts

 1000Hz - 0dB 180° - 0dB	**Locked Mode readout: top line = signal frequency (both channels) and left channel amplitude; bottom line = channel phase difference and right channel amplitude.**
 L: 1000Hz - 0dB R: 1000Hz - 0dB	**Independent Mode readout: top line = left channel frequency and amplitude; bottom line = right channel frequency and amplitude.**
 A: 1000Hz - 0dB B: 1000Hz - 0dB	**Mixed Mode readout: top line = frequency and amplitude of wave 1; bottom line = frequency and amplitude of wave 2.**
 1000Hz - 0dB 100/900ms -30dB	**Pulsed Mode readout: top line = frequency (both channels) and pulse-on amplitude; bottom line = pulse-on time (0-9999ms), pulse-off time (0-999ms) and pulse-off amplitude.**
 20Hz - 0dB 20000Hz 10.0/ 1s	**Sweep Mode readout: top line = start frequency and amplitude (both channels); bottom line = finish frequency (both channels), sweep time (0.1 - 99.9s) and off-time (0-98s and manual).**

Note: values inside green boxes can be selected and varied using the front panel pushbuttons

Table 2: Attenuation accuracy

Setting	Measured Value
–60dB	–59.92dB
–70dB	–69.80dB
–80dB	–79.16dB
–90dB	–89.35dB

Keep in mind that when adjusting the attenuation, pressing the Up button increases the attenuation and thus decreases the signal amplitude.

The only other mode settings (aside from frequencies and amplitudes) are time periods. In the case of pulsed mode, they are specified in milliseconds and have a range of 0-9999 (just under 10 seconds) or 0-999 (just under one second). In sweep mode, they are specified in tenths of a second and seconds, with a range of 0-99.9 seconds and 0-99 seconds respectively.

If you switch away from a mode and then back again later, the previous settings are typically retained. However, some are shared between the modes. For example, independent and mixed mode share all their settings, differing only in how they output the signal (independently to each channel or mixed on both). As a result, changing a setting in one changes both.

The left/right channel amplitudes are shared between all modes except pulse and sweep. Most other settings are independent.

Configuration details

Table 3 shows each setting readout and describes each field. Some require more explanation, as follows:

Status readout: the Status readout is very useful in sweep mode. Not only does it show the frequency as the sweep occurs (it's updated four times a second) but also you can pause and restart the sweep. Pressing the Left button in this readout mode pauses or resumes the sweep, while pressing the Right button starts/restarts it.

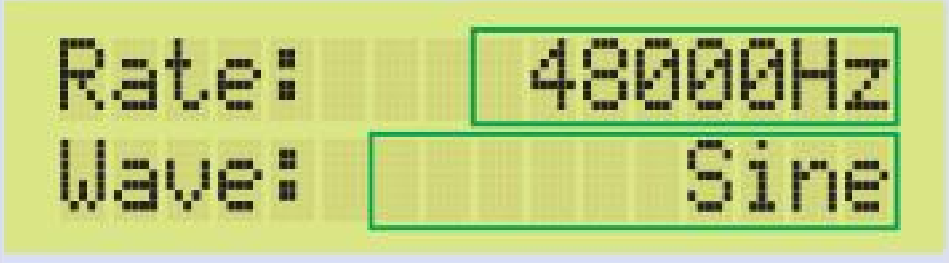
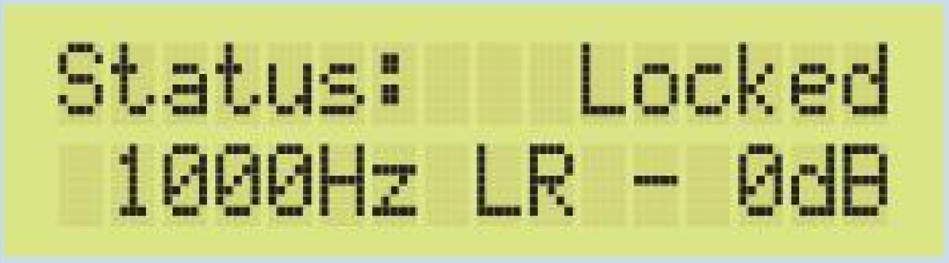
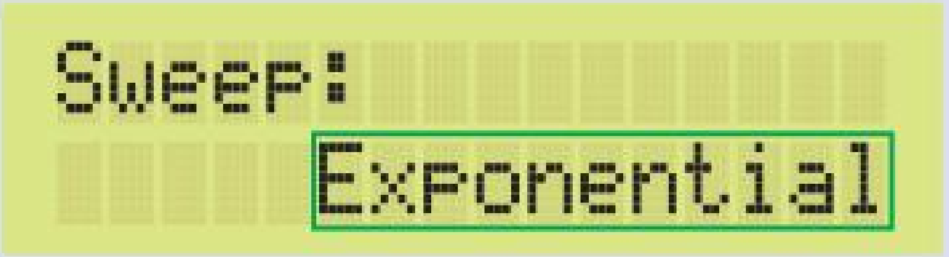
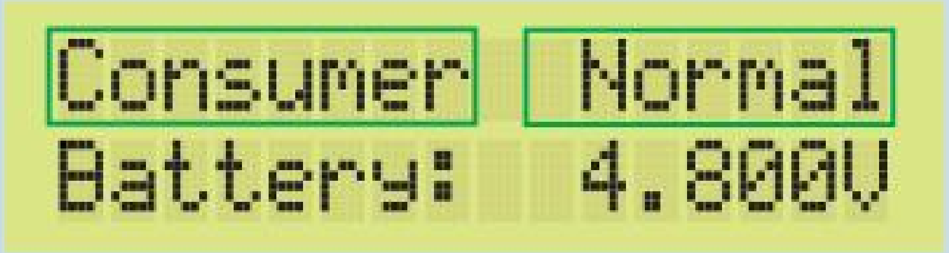
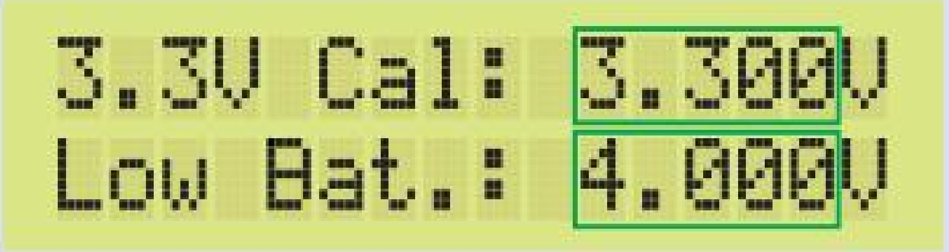
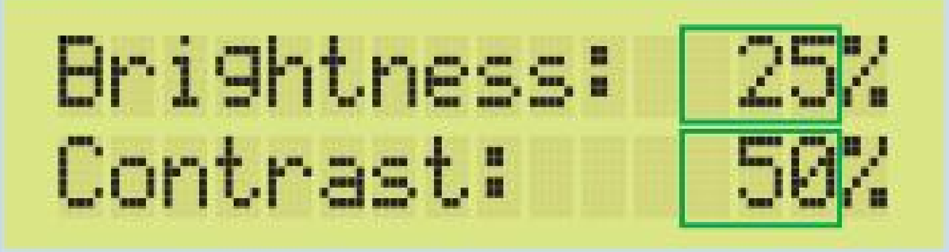
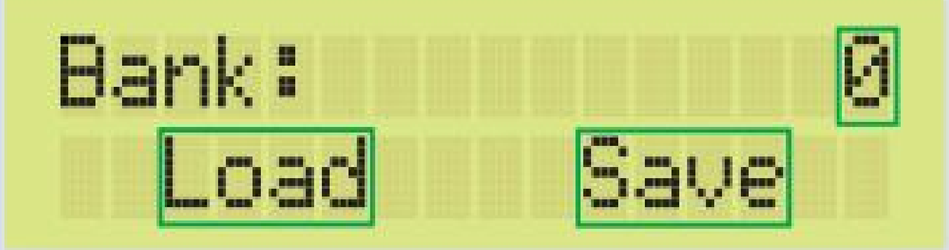
This is especially useful when you are optimising crossover networks or matching a subwoofer to other drivers. If you hear a peak in the output amplitude, you can pause the sweep and read off the frequency.

There may be times when you want a manual sweep; ie, rather than having it loop repeatedly, you can trigger it manually. To do this, set the sweep off time to maximum via the sweep mode readout – it will show 'man' (manual).

It will then only start when you trigger it manually from the status readout using the Right button.

Sweep setting readout: this allows you to choose between Exponential or Linear sweep. Exponential sweep is the default and is usually what you want. In this mode, the frequency doubles or halves at a fixed rate.

Table 3: Setting Readouts

 Rate: 48000Hz Wave: Sine	Output/wave type setting readout: top line = output type (44100Hz, 48000Hz [default], 96000Hz, Analogue); bottom line = signal type (Sine, Square, Triangle, SawtoothUp, SawtoothDn).
 Status: Locked 1000Hz LR - 0dB	Status readout: indicates the current generation mode and mute status. In pulsed and sweep mode, it shows the current frequency and amplitude. 'LR' becomes 'lr' when both channels are muted.
 Sweep: Exponential	Sweep setting readout: first line = setting; second line = sweep type (Exponential [default] or Linear).
 Consumer Normal Battery: 4.800V	S/PDIF setting readout: line 1 = encoding type (Consumer [default] or AES/EBU) plus pre-emphasis setting (Normal [default] or PreEmph); line 2 = battery voltage display.
 3.3V Cal: 3.300V Low Bat.: 4.000V	Battery setting readout: Line 1 = 3.3V regulator output voltage calibration; line 2 = low battery warning voltage setting.
 Brightness: 25% Contrast: 50%	LCD setting readout: line 1 = LCD backlight brightness (0-100%); line 2 = LCD contrast (0-100%).
 Bank: 0 Load Save	EEPROM setting readout: line 1 = Select EEPROM bank (0-9); line 2 = Load all settings from specified bank and Save all settings to specified bank.

Note: values inside green boxes can be selected and varied using the front panel pushbuttons

Linear sweep simply increases the frequency by a set amount over time. As a result, it spends less time at low frequencies and more time at higher frequencies. This mode could be useful if you are using a computer to capture and analyse the output, as it may make analysis simpler.

Keep in mind that while the generator attempts to reach your programmed finish frequency after the specified time has elapsed, in practice this is very difficult to achieve. As a result, with long sweep times, it may be off by a few milliseconds and occasionally the final frequency may actually be a few hertz below that specified.

S/PDIF setting readout: lets you configure the S/PDIF output format, as well as view the current battery voltage.

The first setting, 'Consumer' or 'AES/EBU', determines the format of the Channel Status data sent with the S/PDIF stream. 'Consumer' is the typical format that most CD and DVD players use. On some equipment, this format is limited to 20 bits of precision in the audio data, so you may get slightly higher distortion and worse amplitude control on this setting. However, it is the most widely supported.

'AES/EBU' is the professional standard used by DATs, mixers and high-end sound cards. It allows the full 24-bit precision in the audio samples, as well as sending more complete meta-data. In general, AES/EBU mode is better, provided the equipment that's receiving the signal can handle it.

The second setting allows you to enable the pre-emphasis bit in the S/PDIF stream. This has the effect of enabling the de-emphasis hardware in the receiver (if it has any) and is mainly useful for testing. For example, you can run a 20Hz-20kHz sweep with and without this bit set, and check that the higher frequencies are properly attenuated (ie, de-emphasised) when it is set.

The battery voltage readout lets you keep track of the charge state. Note, however, that the reading is actually a little lower than the real battery voltage (by about 0.3V) due to the Schottky diode (D2) in series with it. This means that if you consider your cells flat when the battery reaches 4.0V (for example), you'll actually want to switch the device off or attach the plugpack as soon as it reads near 4.3V.

Battery setting readout: lets you calibrate the battery voltage monitor – see the 'Calibration' section in Part 2 in the April 2012 issue. It also lets you set the low-battery warning voltage threshold. Once the battery has dropped below this level, the backlight will dim and flash, warning you to charge the battery or switch it off.

During this time, you can continue using the generator. The recommended settings are 3.9V for alkaline cells (actually 3.6V) and 4.3V for NiMH cells (actually 4.0V).

Regardless of this setting, if the voltage reading drops below 3.5V for some time, the microcontroller will go into sleep mode. The 'Battery flat!' message is then displayed and all other functions cease. Backlight flashing continues, although at a reduced brightness.

When that happens, the current drain drops from 100mA or more to about 30mA. This will still drain the battery, but not as quickly.

LCD setting readout: here you can adjust the display contrast and backlight brightness. You may need to change them according to lighting conditions, viewing angle or temperature. If you manage to reduce the contrast so much that the display becomes unreadable, switching the power off and on will typically restore it to the default.

The backlight brightness selection is a compromise because as you increase it, you increase the current drain at the expense of battery life. The default value of 25% is sufficient for good display visibility under most conditions and only adds about 30mA to the battery current.

EEPROM setting readout: lets you define the default settings (ie, those loaded at power on), as well as store up to nine other setting configurations. Bank 0 is loaded at switch-on, so if you save to bank 0 you are setting the defaults.

To save settings, select the appropriate bank number, then move the cursor to 'Save' and press the Up or Down button. The readout will change to 'Saved' and the current configuration and mode settings will be stored in that slot. You can then switch the generator off, or continue using it. You can even change the bank number and save to another one if you wish.

To load settings, the procedure is essentially the same. You select the bank number you want, move the cursor to 'Load', and press the Up or Down button. The readout changes to 'Loaded' and the current settings are replaced with those stored in EEPROM. Almost everything will be set just as it was when you saved to that bank. Note that attempting to load a bank that has nothing saved in it has no effect.

The additional banks can be handy if you often repeat certain tests and they involve a specific configuration. You can store commonly used configurations in banks 1 to 9, and hence save yourself the time of having to adjust multiple settings to the same values again later.

Wave types

An example of each wave type is shown in the screen grab panel opposite. Each has been sampled using both the analogue outputs of the Digital Audio Signal Generator and also the High-Quality Stereo DAC (Sept to Nov 2011), the latter fed from the generator's S/PDIF output.

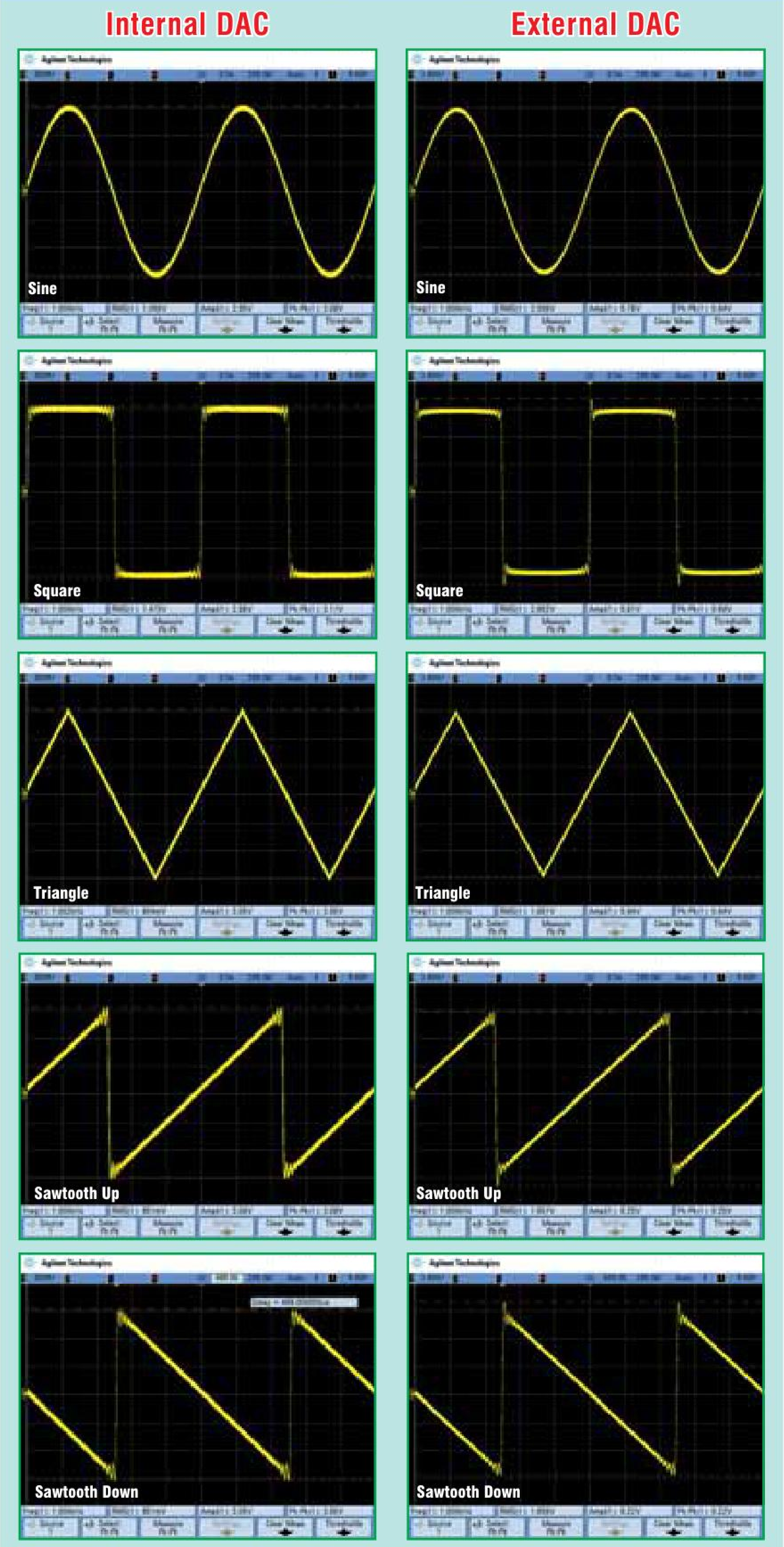
The high-frequency oscillations apparent in both the square and sawtooth signal outputs from both DACs are a result of their delta-sigma architecture. These types of waveforms are unnatural due to their discontinuous nature – ie, they contain vertical lines whereas natural waveforms normally do not.

As a result, the digital sinewave signal interpolation is smoothing the abrupt transitions, with the filter inserting some high-frequency waves before and after each transition to cover up the discontinuity. The result is what you see here. We know that the digital circuit must be responsible for the oscillations as they occur equally, both before and after each transition.

On the other hand, the external DAC has some overshoot with the square and sawtooth waves, which is presumably due to the analogue filter circuit after the DAC chip itself. It only occurs post-transition.

The sinewave signal does not suffer from this issue because it is continuous. The triangle signal does have a discontinuous first derivative (at the point of each triangle), but since it has a continuous waveform it

Example wave types



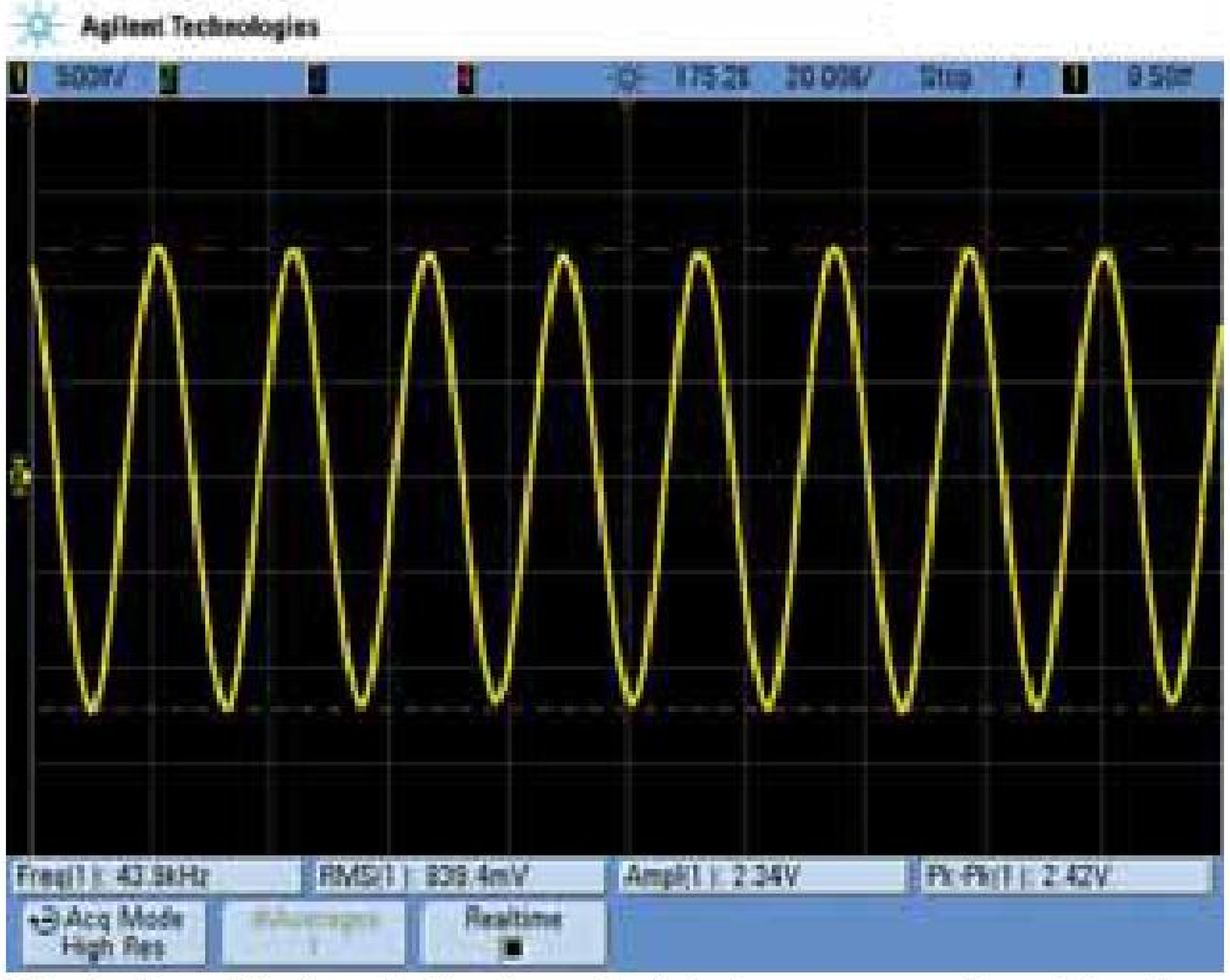

Agilent Technologies
Freq(1): 43.9kHz
RMS(1): 838.4mV
Ampl(1): 2.34V
Pk-Pk(1): 2.42V
Acq Mode
High Res
Realtime

Fig.1: the effects of aliasing start to become noticeable at 44kHz. Note the subtle variations in the signal amplitude.

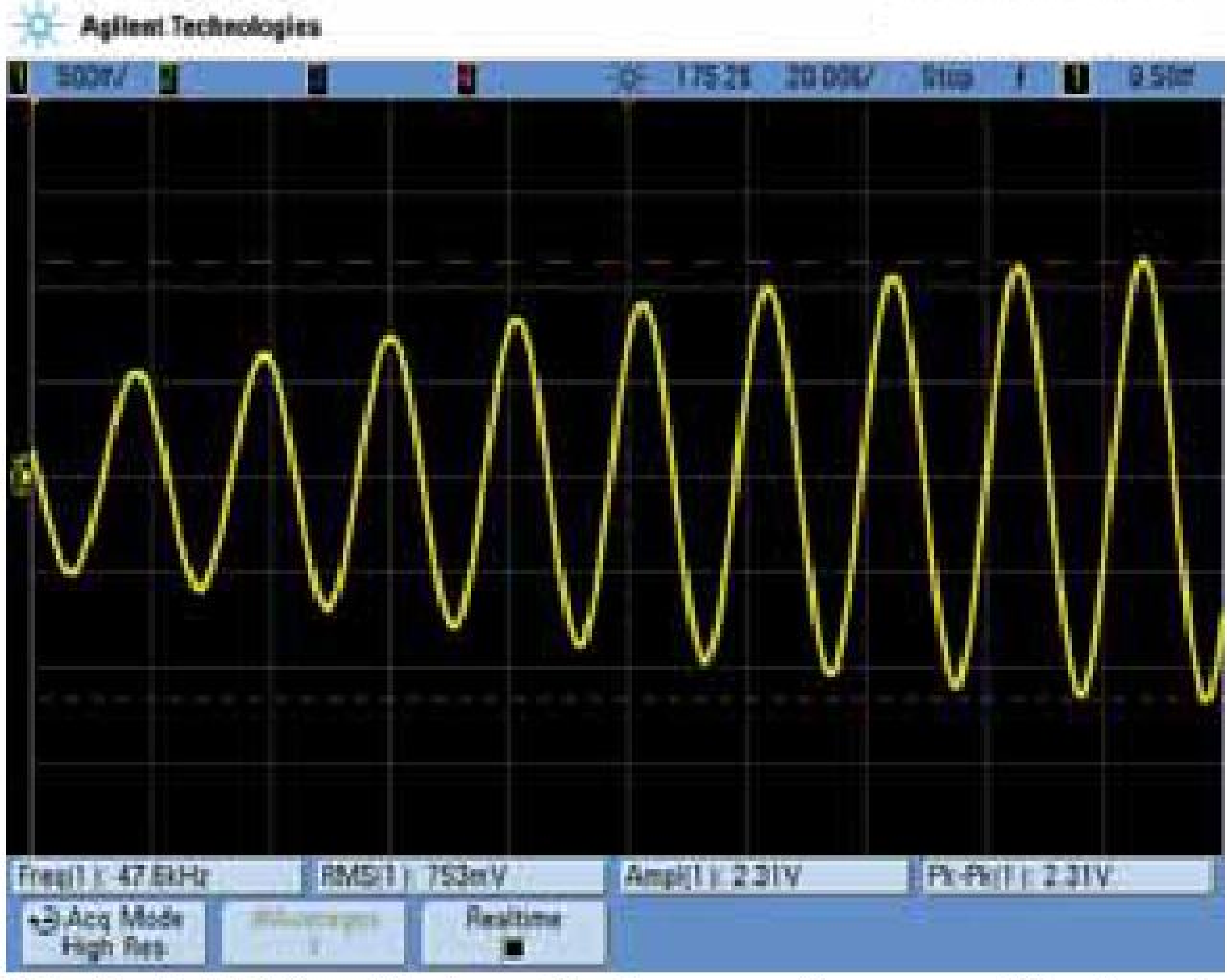

Agilent Technologies
Freq(1): 47.6kHz
RMS(1): 753mV
Ampl(1): 2.31V
Pk-Pk(1): 2.31V
Acq Mode
High Res
Realtime

Fig.2: at 47kHz, aliasing effects are quite severe (the input data in this case actually has constant amplitude).

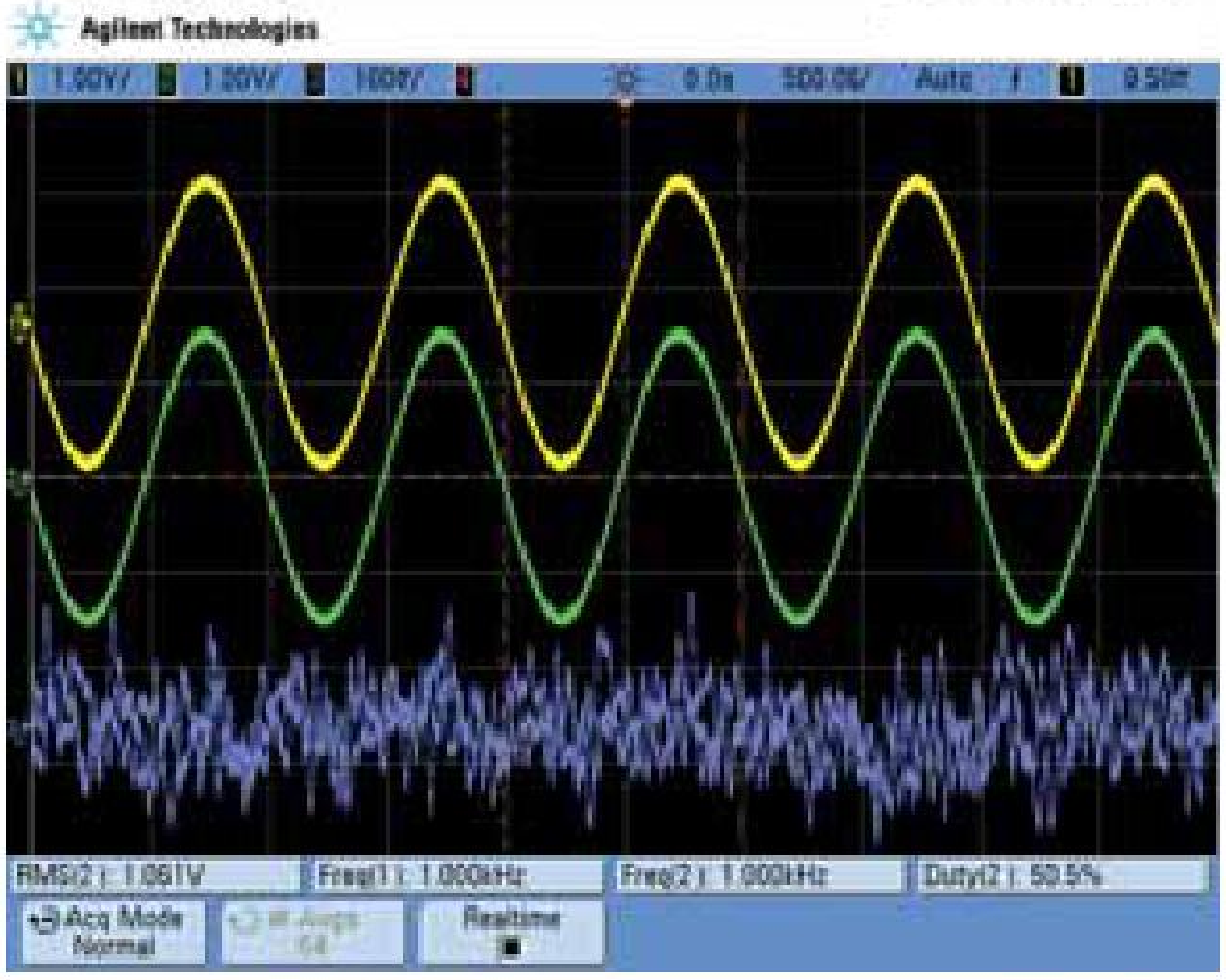

Agilent Technologies
RMS(2): 1.061V
Freq(1): 1.000kHz
Freq(2): 1.000kHz
Duty(2): 50.5%
Acq Mode
Normal
Realtime

Fig.3: this scope grab shows the analogue output distortion residuals (0.06%) for a 1kHz sinewave and 0dB attenuation.

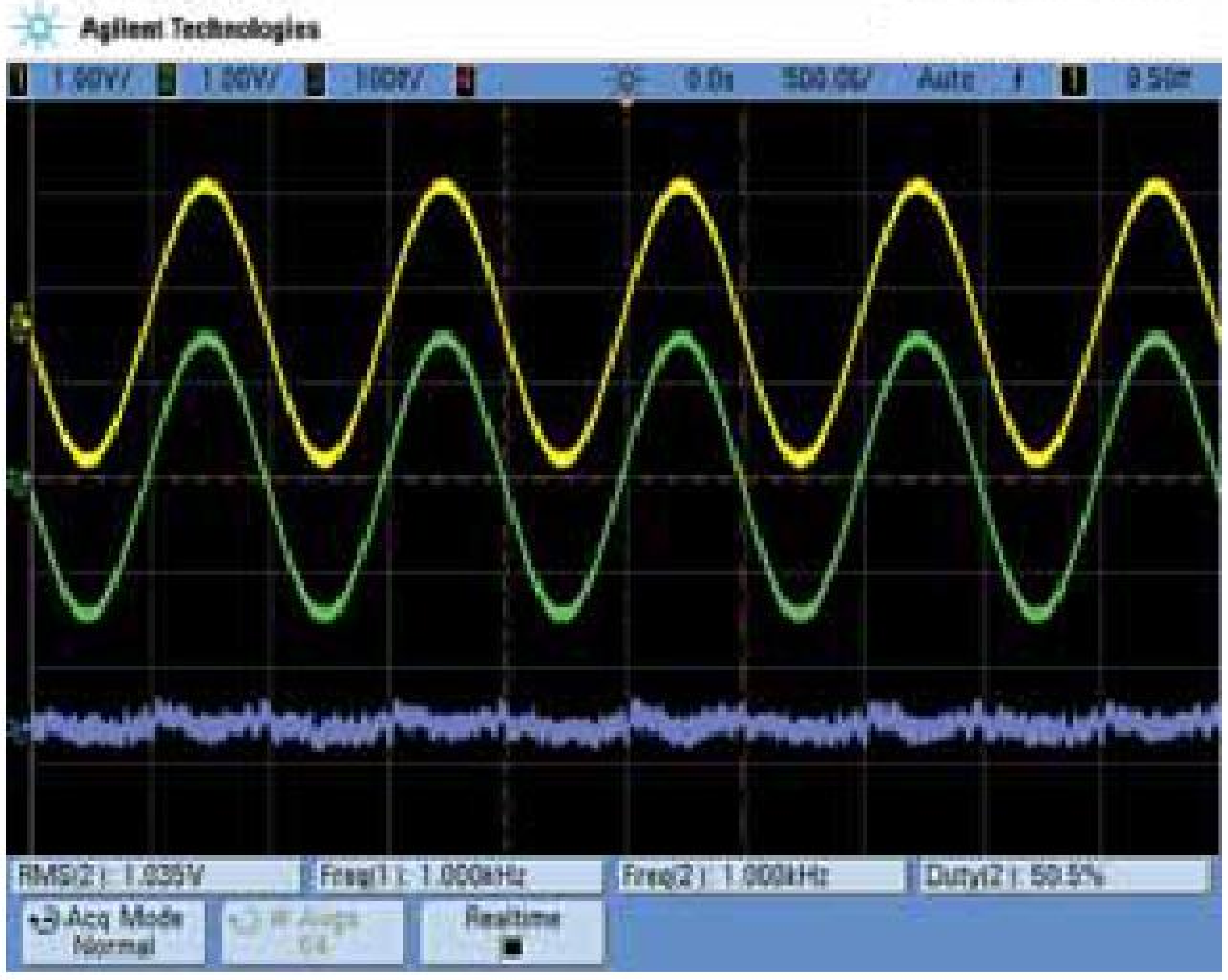

Agilent Technologies
RMS(2): 1.035V
Freq(1): 1.000kHz
Freq(2): 1.000kHz
Duty(2): 50.5%
Acq Mode
Normal
Realtime

Fig.4: the distortion residuals drop to just 0.0006% (1kHz, 0dB attenuation) when using the High-Quality Stereo DAC.

is not badly affected. There is a little rounding at the tips, again likely due to the digital sine signal interpolation, but it is minimal.

Aliasing

There is an additional issue related to the digital filtering, and that is aliasing. In fact, all DACs suffer from it to some extent.

When the sample rate is set to 96kHz, the highest frequency signal you can generate is 48kHz. There is a wrinkle, though – as you get very close to 48kHz, there are so few samples per signal that the signal form can no longer be properly represented.

Basically, the digital data becomes ambiguous – while the frequency information can still be extracted, the amplitude of each wave is no longer clear. Aliasing starts to become noticeable above 44kHz (note the subtle variations in amplitude shown in the scope shot of Fig.1) and it is quite severe at 47kHz (Fig.2).

The input data for the second capture actually has a constant amplitude. However, aliasing does not increase monotonically with frequency. There is no aliasing at exactly 48kHz, for example.

What this means is that you should generally avoid frequencies between 45% and 50% of the sample rate, except for exactly half (ie, 48kHz in this case). That way, aliasing will not typically be an issue.

By the way, if you want to make sound effects for a science fiction film, try setting the signal type to triangle and the sample rate to 48kHz, then initiate a sweep from 12kHz to 24kHz. What you then hear is due to the aliasing causing frequency shifts in the output.

Distortion

There's another issue to keep in mind when selecting the sample rate. When the output frequency is below about 10kHz, the sinewave signal distortion is actually lower at 48kHz sampling than at 96kHz sampling. So, if you're only going to generate low-to-mid frequency sinewaves and need the least distortion, stick with the 48kHz sampling rate. You can still switch to 96kHz when necessary for higher frequency output signals.

Finally, if you have an oscilloscope, it's a good idea to connect the generator's outputs to it and try out the various modes. By doing this, you will quickly get used to the interface and get a feel for how the various modes work. ***EPE***

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EPE EXCLUSIVE

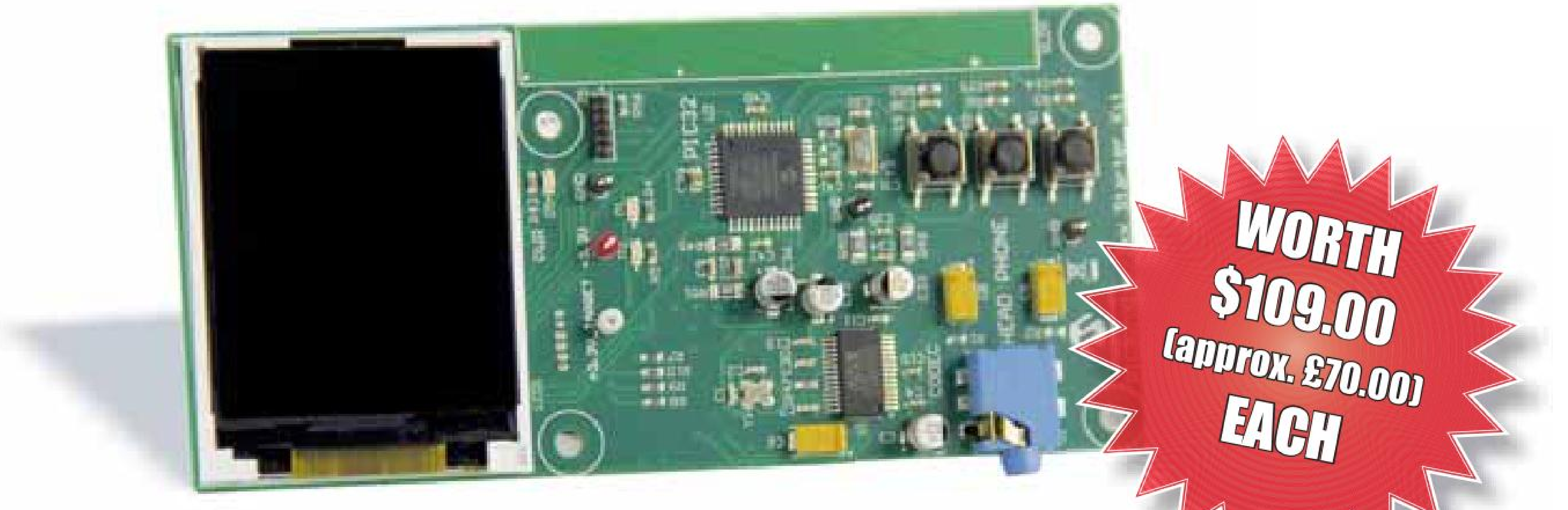
Win a Microchip MPLAB Starter Kit for PIC32MX1xx/2xx

EVERYDAY PRACTICAL ELECTRONICS is offering you the chance to win a Microchip MPLAB Starter Kit for PIC32MX1xx/2xx (DM320013). The PIC32MX1/MX2 Starter kit is a complete hardware and software tool suite for exploring applications based upon Microchip's new low cost, high performance PIC32MX1/MX2 devices.

PIC32MX1 and MX2 MCUs are low pin count 32-bit PICs that provide 61 DMIPS of performance in packages as small as 5mm × 5mm, for space-constrained and cost-sensitive designs. They are Microchip's smallest and lowest-cost PIC32 microcontrollers, and are the first PIC32 MCUs to feature dedicated audio and capacitive-sensing peripherals. They also feature USB on-the-go (OTG) capabilities, making them ideal for developing audio accessories and other applications in the consumer, industrial, medical and automotive markets.

This MPLAB Starter Kit is perfect for development of basic user interfaces with mTouch buttons and high quality audio. The board is pre-loaded with demo code for an audio player. Simply download a free copy of MPLAB IDE and the demo code source from the web to jump start your development effort.

Key features of Microchip's MPLAB Starter Kit:
● 24-bit audio playback ● Integrated programmer debugger ● USB powered ● 2-in colour TFT display – 220 × 176 pixel ● mTouch slider and buttons ● PIC32MX250F128 with 128KB of Flash, 32KB RAM ● Micro SD Flash card.



HOW TO ENTER

For the chance to win an MPLAB Starter Kit for PIC32MX1xx/2xx, visit: **http://www.microchip-comps.com/epe-mplab** and enter your details in the online entry form

CLOSING DATE

The closing date for this offer is 30 June 2012

By NICHOLAS VINEN

Low-Power
USB Charger

Low-Power Car/Bike USB Charger

Looking for an efficient USB charger that can operate from a 12V car battery? This unit functions at up to 89% efficiency and can charge USB devices at currents up to 525mA. Best of all, it won't flatten the battery if it's left permanently connected, as long as you remember to unplug the USB device.

THERE are lots of USB chargers on the market, but this device has two stand-out features: high efficiency and low standby current. In fact, its standby current is just 160μA, a figure that's well below the self-discharge current of most lead-acid batteries.

This means that you can leave the device permanently connected and it will not cause that battery to go flat (or at least, not much faster than it would of its own accord).

Making a connection

Why is this useful? USB car chargers are cheap and plentiful, but finding one with a low enough quiescent current for permanent battery attachment is difficult. Even those marketed as 'low idle power' devices don't specify how much current they draw on standby.

We tested a regular charger and found that it consumed 13mA with no load. Like many others, it has an integrated power LED and that would contribute significantly to the standby current consumption. However, since the cigarette lighter socket is only powered when the engine is running, there is no real reason for the designers of these car supplies to keep the quiescent current low.

Cigarette lighter plugs are also pretty lousy DC connectors. They often don't fit well and can easily fall out. With this project, you can use whatever type of connector is most convenient. In many cases, this will mean input wires terminated in spade or eyelet lugs.

While this may seem like a very specific application, there are many other uses for a low-quiescent current 12V DC to 5V DC converter. For example, remote monitoring stations often run from a 12V SLA (sealed lead-acid) battery topped up by a solar panel. These stations invariably contain a microcontroller and other circuitry, which need a 3.3V to 5V supply.

The current consumption in these devices will be low most of the time, but occasionally the microcontroller will wake up and activate a radio module or other circuitry which can draw more current. This charger can deliver that current – up to 500mA – while still being miserly with battery power when the load is light.

In addition, because its efficiency is high (up to 89%), hardly any battery power is wasted, even when the load is drawing 500mA.

What is quiescent current?

So what exactly is quiescent (or standby) current? This term often comes up in IC data sheets. Its simple meaning is 'idle current', although when talking about regulators, it sometimes refers to the current consumed by the device itself, rather than by what it is supplying.

In most fixed regulators, this is the same as the 'ground pin current'. There are typically two current flows in a regulator – from the input to the output and from the input to ground. The ground pin current is the power consumed by the regulator itself.

At higher currents, most regulators consume more current than they do at

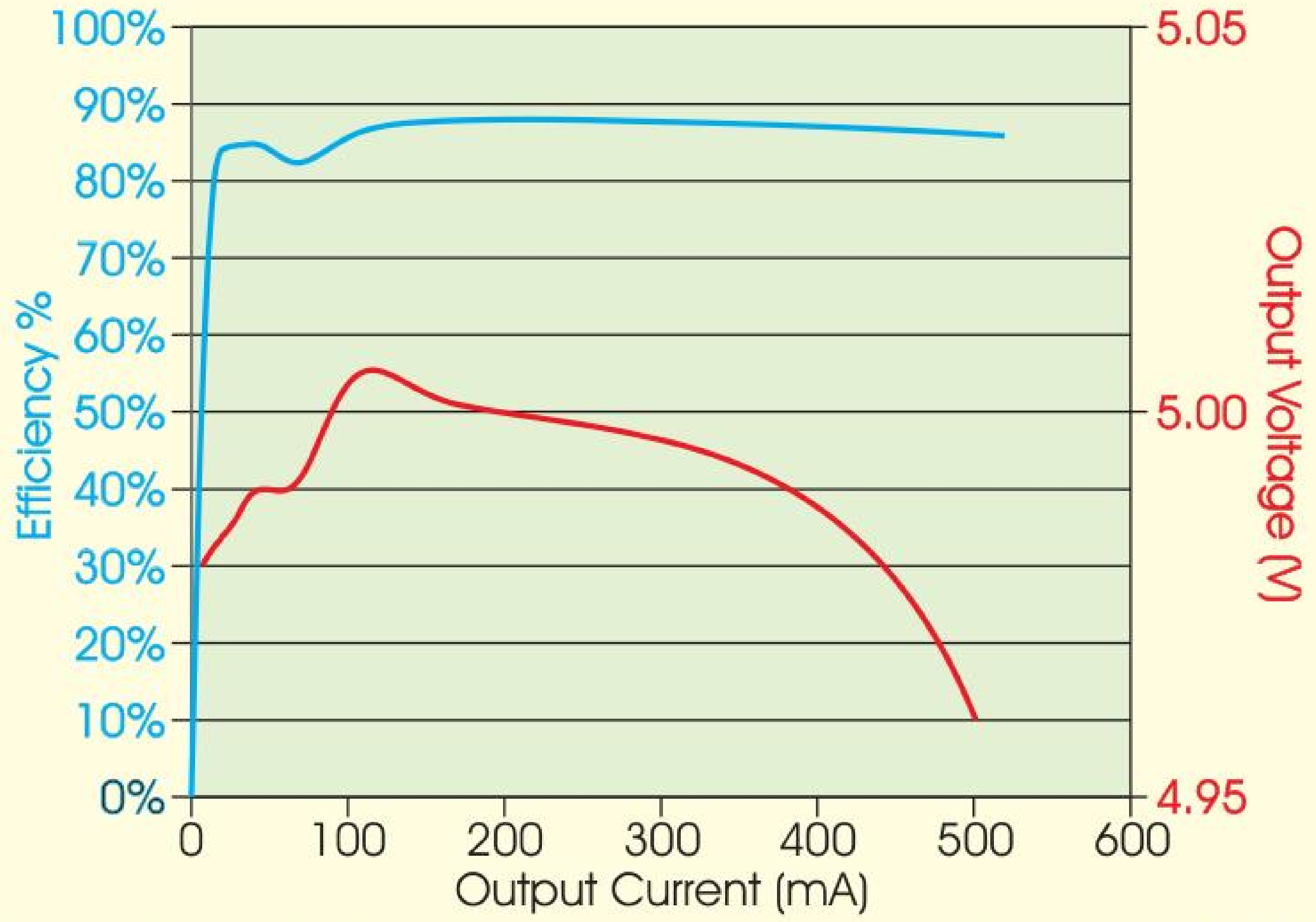


Fig.1: this graph plots the efficiency and output voltage over the full output current range. As shown, the efficiency is over 80% for any output current above 10mA.

idle. As a result, the quiescent current may be specified for different output currents, including the no-load case. Although the device is arguably no longer 'quiescent' when it is delivering an output, the term is often used this way.

Since we primarily want to minimise power consumption with no USB device attached, the idle current is critical for this design. What's more, a device with low idle current will usually also have low ground-pin current at higher loads. This is just what we want, since the overall efficiency is determined by the combination of the conversion efficiency and ground-pin current.

USB charging issues

Basically, this device is a DC-to-DC converter. You feed 12V DC (or thereabouts) in at one end, and it delivers a 5V DC output at the other end. It complies with the USB 2.0 specifications with regard to power; ie, it supplies at least 500mA at 4.75V to 5.25V.

However, for some devices, this current level is insufficient for them to operate, and charge their battery simultaneously. Many of these devices require a custom cable or special USB data pin connection arrangement before they will attempt to draw more than 500mA, so that they can do both at the same time.

This shouldn't be a big problem, since such devices should be able to operate without simultaneously charging the battery. The battery can then be charged when they are switched off (ie, no longer being used).

Unfortunately, many USB-powered devices provide no way to switch modes like that. However, if your device can operate normally from a computer's USB port, it should work fine with this charger, since they supply the same amount of power.

There's just one wrinkle here. If your USB device switches to a data transfer mode when plugged into a computer USB port, it may behave the same way when connected to this charger, even though the data lines (D+ and D–) aren't connected. Its battery will still charge, but the device may have to be unplugged to be used.

Devices which typically behave in this manner are car GPS units. Plug them into a PC's USB port and they immediately switch to data transfer mode (ie, for downloading software upgrades and map updates). This doesn't stop the internal battery from charging via the USB port – it's just the the device must be unplugged in order to use it as a GPS.

Design considerations

The first step in designing this device was to find an appropriate switch-mode regulator IC. One candidate that satisfies all the requirements is Linear Technology's LTC1174HV. The HV (high-voltage) version can run from 6V to 17.5V (for 5V output) and consumes only 130μA at idle, with a maximum output of around 500mA (this is also the most current that can be drawn from a single USB port). The LTC1174HV is quite efficient too.

Unfortunately, it's hard to get the HV version in a DIP package. None of our usual vendors stock it, so we had to order the low-voltage version, which has an absolute maximum rating of only 13.5V.

This problem was solved by adding a low quiescent current linear pre-regulator to the design. This prevents the IC's supply from exceeding 13V, regardless of the battery voltage. The only drawback is that it reduces the efficiency slightly at higher battery voltages, although it doesn't add much to the idle current.

However, since the battery will only be above 13V while it is being charged, the loss of efficiency under this condition doesn't really matter.

The other issue is that while the data sheet says that switching will occur at around 100kHz with the components we are using, at light loads the burst mode causes switching to occur at much lower frequencies – in some cases, well into the audio range. As a result, the inductor used in the circuit makes some noise with light loads.

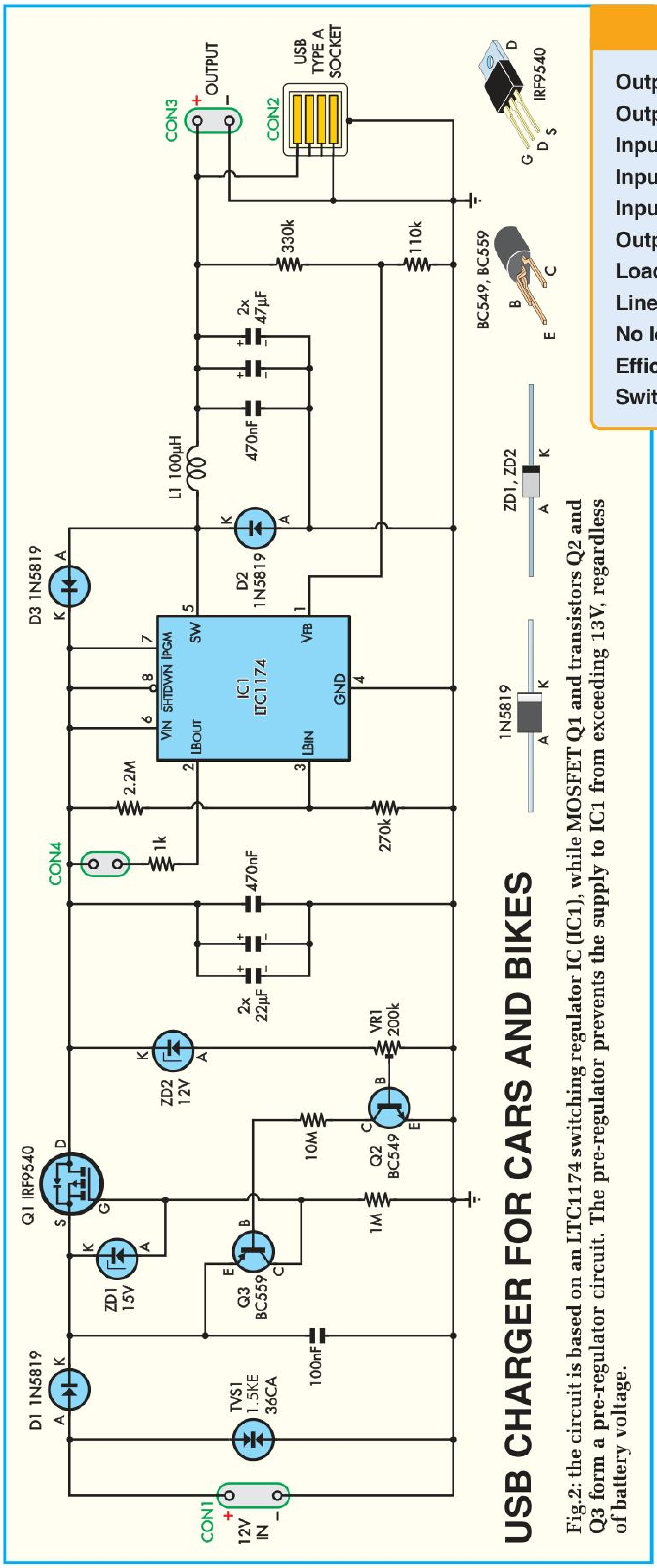
We managed to tweak the design to minimise this noise. If you listen carefully you can hear it, but if the board is mounted in a box and placed in a moving vehicle, it becomes inaudible.

Circuit description

Refer now to Fig.2 for the full circuit diagram. IC1 is the main switching regulator IC, while MOSFET Q1 and its associated parts form the low current pre-regulator circuit.

Power from the external 12V DC source is fed in via CON1. Immediately following this, a 36V AC transient voltage suppressor (TVS1) across the input damps any positive voltage spikes that may appear on the supply line (eg, due to devices switching on or off). Diode D1 then provides reverse polarity and negative spike protection.

The pre-regulator circuit (based on Q1) is a low quiescent current MOSFET-based design, especially developed for this type of application. The transconductance of MOSFET Q1 is controlled so that the voltage at its drain (D) will not exceed a preset value. This is done using Zener diode ZD2, trimpot VR1 and transistors Q2 and Q3.


CON3
+
−
OUTPUT
CON2
USB TYPE A SOCKET
IRF9540
G D S
D
BC549, BC559
B
C
E
330k
110k
2x 47µF
470nF
L1 100µH
D2 1N5819
K
A
ZD1, ZD2
1N5819
D3 1N5819
IC1 LTC1174
VIN
SHTDWN
IPGM
SW
VFB
GND
LBIN
LBOUT
1
2
3
4
5
6
7
8
2.2M
1k
CON4
470nF
270k
2x 22µF
VR1 200k
ZD2 12V
10M
Q2 BC549
Q1 IRF9540
1M
ZD1 15V
Q3 BC559
100nF
D1 1N5819
TVS1 1.5KE 36CA
CON1
12V IN

USB CHARGER FOR CARS AND BIKES

Fig.2: the circuit is based on an LTC1174 switching regulator IC (IC1), while MOSFET Q1 and transistors Q2 and Q3 form a pre-regulator circuit. The pre-regulator prevents the supply to IC1 from exceeding 13V, regardless of battery voltage.

Performance

Output voltage: 4.75V to 5.25V
Output current: approximately 525mA
Input voltage range: 6V to 16V DC
Input current requirement: maximum 300mA at 12.0V
Input current with output shorted: 4.3mA
Output ripple: 110mV p-p, 30mV RMS at 500mA
Load regulation: 50mV at 12V, 0-500mA (1%)
Line regulation: 16mV at 450mA, 7.0V to 13.0V (0.32%)
No load input current: 160µA
Efficiency: up to 89% (see Fig.1)
Switching frequency: 10Hz to 120kHz

In this case, the voltage on Q1's drain is set to 13V, and VR1 allows you to trim this value. We need to make sure the LTC1174 (IC1) can't be damaged and this provides a small safety region (ie, 0.5V) between its supply voltage and its maximum rating.

How it works

The circuit works as follows. When power is applied, Q1's gate (G) is pulled low via a 1MΩ resistor, turning it on. Q1's output voltage then rises until ZD1, a 15V Zener diode, begins to conduct and pass current to trimpot VR1. Once VR1's wiper (moving contact) exceeds 0.65V, transistor Q2 turns on and this then turns on Q3.

As a result, current now flows though Q3 and the 1MΩ resistor. This in turn increases Q1's gate voltage and switches it off. By suitably adjusting VR1, Q1's output can be accurately set to 13V.

The nominal 13V supply from the pre-regulator is decoupled using two 22µF 16V tantalum capacitors and a 470nF MKT capacitor. Tantalum capacitors were chosen for two reasons: (1) they have much lower leakage than aluminium electrolytics and (2) they have a lower ESR at high frequencies than other electrolytics.

Any capacitor leakage across the input or output of the switch-mode regulator adds to the quiescent current of the circuit, and we want to keep leakage to a minimum. The switch-mode circuit can operate at frequencies in excess of 100kHz (occasionally as high as 1MHz) in burst mode, so we need to make sure the capacitors will be effective at high frequencies.

The switch-mode regulator section is based on the schematic shown in the LTC1174 data sheet ('High Efficiency 3.3V Regulator'). However, the 50µH inductor has been increased to 100µH and we've added a voltage divider, since we need a 5.0V output instead of 3.3V. See: **http://cds.linear.com/docs/Datasheet/1174fe.pdf**

Pin 7 and pin 8 of IC1 are tied to the positive supply rail. Keeping pin 8 high ensures that the IC is always enabled, while pulling pin 7 high selects the higher peak current limit (600mA).

That way, the current limiting will not kick in until an average of exactly 500mA is being supplied.

The 330kΩ and 110kΩ resistors across the output form a 4:1 voltage divider. This sets the output voltage. In operation, the LTC1174 adjusts its output voltage so as to keep its V_{FB} pin (pin 1) at 1.25V. This means that the output voltage will be 1.25 × 4 = 5.0V.

If you want to change the output voltage, use the formula $R3 = R4 \times ((V_{OUT}/1.25) - 1)$, where R4 is 110kΩ. For example, to set the output to 3.3V, replace R3 with 180kΩ. In this case, the output would be taken from CON3 (which is a polarised 2-pin header) rather than from the USB socket.

Low battery

The 2.2MΩ and 270kΩ resistors form a voltage divider which is applied to the L_{BIN} (Low Battery Input) pin of IC1. If the supply falls below 11V, pin 2 will sink current (ie, it goes low). Header CON4 enables a high-brightness LED to be fitted to indicate the low-battery condition, but note that once it comes on, it will then run the battery flat even faster!

In short, this LED is optional and should be left out unless you have a specific reason for using it.

By contrast, diode D3 is necessary. It's included to protect IC1 from an input supply short circuit – as unlikely as that may be. Without it, if an input short were to occur, IC1 could be destroyed.

Following inductor L1 (which serves as the switchmode energy storage element), the output voltage is filtered by two 47µF tantalum capacitors and a parallel 470nF MKT capacitor. This is not a great deal of capacitance, but thanks to the good high-frequency performance of tantalum capacitors, the output ripple is typically no more than 110mV peak-to-peak and 30mV RMS. Larger capacitors could be used here, but their leakage currents would be higher.

The 5V output is fed to two different output sockets connected in parallel. CON2 is a Type A USB socket for recharging USB devices. For other devices, the output can be taken from 2-pin polarised header CON3.

Note that the operating temperature range for the LTC1174CN8 is specified as 0 to 70°C. If you live in a cold or extremely hot climate and will be using this device outdoors (eg, mounted outside the cabin of a vehicle), then you may need to use the LTC1174IN8 IC instead. This can operate from –40°C to 85°C.

Input limitations

Normally, the supply voltage will be in the range of 12V to 14.4V. However, the regulator will operate just fine over a range of at least 9V to 15.6V. In a vehicle, it is not unusual to get short-term voltage spikes in both directions. Suppressor TVS1, diode D1 and the pre-regulator combine to protect the device from these spikes.

Voltages between –36V and 0V will not harm the regulator, since D1 will not conduct. D1's reverse breakdown voltage is –40V, but TVS1 should absorb spikes below –36V anyway.

Above 15.6V, the regulator will continue to operate normally, all the way up to 36V, at which point the TVS clamps the supply voltage. We tested the regulator to 30V and it ran normally. However, if you were to run the regulator at high current and high voltage, Q1 would eventually overheat, since it has no heatsink.

This means that while the regulator will run off voltages above 15.6V, as can happen in a vehicle from time to time, it must not be run at high voltages for extended periods. With a maximum input current of about 220mA at up to 15.6V, MOSFET Q1's dissipation will not normally exceed 572mW.

Buck regulation

The LTC1174 has several modes, but works similarly to a normal 'buck converter' at high output currents.

A 'buck converter' is the most common type of step-down DC/DC converter. It requires a single switch (normally a transistor), an inductor and a capacitor. Fig.3 shows the basic scheme, and it works as follows.

When the switch is closed, current flows through inductor L1 into the load (Path 1). This current slowly builds up from zero to a peak value. When this peak current is reached, the switch opens and current flows through diode D1 to discharge the inductor's energy into the load (Path 2).

Capacitor C1 is included to act as a reservoir, to smooth out the voltage produced across the load. This voltage is dependent on the load and duty cycle of switch S1 (ie, the time that it is closed compared to the time that it is open). It's also dependent on the peak current through L1 and the input voltage.

This type of circuit can be very efficient because voltage control is

Parts List

1 PC board, code 844, available from the *EPE PCB Service*, size 62mm × 49mm
1 UB5-size plastic box – see text
1 2-pin terminal block (5.08mm pitch)
1 PC-mount horizontal Type A USB socket (Jaycar PS0916)
2 2-pin polarised headers (2.54mm pitch)
2 2-pin polarised header connectors (2.54mm pitch)
1 100µH high-frequency 1.13A bobbin inductor (Altronics L6222)
1 small rubber grommet
1 M3 × 6mm machine screw
1 M3 star washer
1 M3 nut
1 8-pin machine tooled socket (optional)
1 200kΩ horizontal single-turn trimpot (VR1)

Semiconductors
1 LTC1174CN8 (IC1) (available from Farnell)
1 IRF9540 MOSFET (Q1)
1 BC549 transistor (Q2)
1 BC559 transistor (Q3)
1 1.5KE36CA transient voltage suppressor (TVS1)
1 15V 1W Zener diode (ZD1)
1 12V 1W Zener diode (ZD2)
3 1N5819 Schottky diodes (D1 to D3)

Capacitors
2 47µF 16V tantalum
2 22µF 16V tantalum
2 470nF MKT
1 100nF MKT

Resistors
1 10MΩ
1 2.2MΩ
1 1MΩ
1 360kΩ*
1 330kΩ
1 300kΩ*
1 270kΩ
1 110kΩ
1 1kΩ

* May be necessary to adjust regulator output – see text

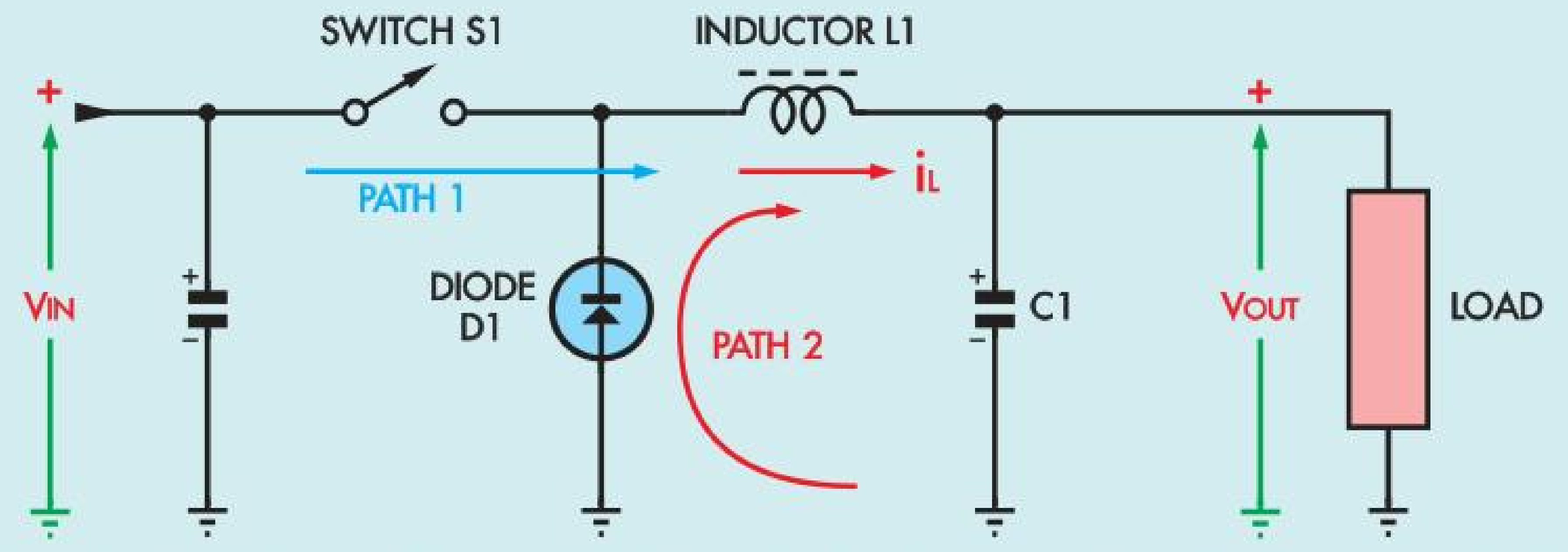


Fig.3: basic scheme for a switch-mode buck converter. Voltage regulation is achieved by rapidly switching S1 and varying its duty cycle. Current flows via path 1 when S1 is closed and path 2 when it is open.

achieved by rapidly switching the input. The small amount of power dissipated is mainly due to voltage losses in the switching device (in practice, S1 is a switching transistor or MOSFET) and in L1 and D1.

The USB Charger operates in similar fashion, but in this case the the switching is performed inside IC1 (LTC1174).

Many buck regulators operate at a fixed frequency, using PWM (pulse-width modulation) to control the switch duty cycle, and thus the output voltage. By contrast, the LTC1174 has a 'fixed off-time' configuration. It varies the switch duty cycle by controlling the length of the 'on-time', ie, how long the switch is kept on for each pulse. This is a power-saving feature – it means that the frequency drops at light loads and the less the internal MOSFET has to switch, the less power is consumed by the IC itself.

When the internal MOSFET switches on, current flows from V_{IN} (pin 6) to SW (pin 5) and through inductor L1, charging the output capacitors. During this period, the magnetic field generated by the inductor increases.

Conversely, when the internal MOSFET switches off, the magnetic field collapses and this continues driving current into the output capacitors. Since the internal transistor is off, the current instead flows from ground through diode D2, and then through the inductor.

It is this charging and discharging of the inductor's magnetic field which allows for efficient voltage conversion. When the internal transistor is on, the inductor nominally has 12V at its switch end and 5V at the output end. If the inductor was a resistor, then more than half the power would be wasted as heat.

There are losses in this process, which is why switchmode regulator efficiency is never 100%. However, it is still a great deal better than linear regulation. With a 13V input, a 5V output and 500mA output current, the input current is around 220mA. This gives an efficiency of (5 × 0.5)/(13 × 0.22) = 87%. A linear regulator under these conditions would have just 5/13 = 38.5% efficiency (assuming that the input and output currents are equal).

If the instantaneous current through the inductor exceeds the IC's internal current limit (nominally 600mA), the internal transistor switches off and the switch off-time is extended from 4µs to around 12µs. This gives the inductor time to discharge if the output is shorted.

Current limiting

One reason for this current limit, apart from stopping IC1's internal transistor from overheating, is that inductors with non-air cores can 'saturate'. Essentially, the core can only hold a certain amount of magnetic flux and its inductance rapidly drops when that level is reached. When it drops far enough, the inductor is essentially just a wire and if the switch is still on, a lot of current can flow through it.

Because the current through the inductor is ramping up and down as the transistor switches, the average current is less than the peak current. That is why, with a 600mA limit, we can only draw up to 500mA. The current limit kicks in soon after that, and the output voltage drops until the current draw decreases below the limit.

This protects against short-circuits at the output, as well as inductor saturation.

Burst mode

At lower currents, IC1 goes into 'burst mode'. It delivers several very fast pulses of current to the inductor (L1)over a short period, bringing the output voltage slightly above 5V. It then switches off and waits for the output voltage to drop below 5V and then starts pulsing again.

As it is waiting for the voltage to drop, the IC is in 'sleep mode' and consumes very little power. The result is that at light loads, ground pin current is substantially lower than it would otherwise be without this burst mode.

While the delay between the bursts makes the effective frequency of operation much lower than at full power, the frequency of the bursts themselves is actually quite high. Frequencies as high as 1MHz were measured.

This means that the noise generated by the inductor is a sub-harmonic of the switching frequency, caused by magnetostriction of the inductor's core.

If there is nothing attached to the regulator's output, the feedback voltage divider becomes the only load. Because the output voltage decays very slowly, the period during which the IC sleeps in burst mode becomes several hundred milliseconds. It is this long sleep period that allows the regulator to have a very low quiescent current with light loads or no load (approximately 140µA).

Construction

Building this unit is easy. All the components mount on a small PC board coded 844, size 62mm × 49mm. This is board is available from the *EPE PCB Service*.

The board snaps into the integral channels in a standard UB5-size plastic box. The USB socket is accessed through a hole cut in one side of the box, while a hole at one end provides access to the input screw-terminal block.

If you want something that's a bit more robust, a small IP67-rated box can be used instead. In this case, the board can be mounted on M3 × 12mm tapped stand-offs and secured using M3 × 6mm machine screws and washers.

Note that because this unit is likely to be exposed to a lot of vibration, we have not specified a socket for the IC. You can use one if you prefer, but make sure it is a machine-tooled type, as the IC is less likely to work its way loose.

Before starting the assembly, carefully check the PC board for defects. Most of the underside is covered by a ground plane. Make sure that there are no unintentional connections between

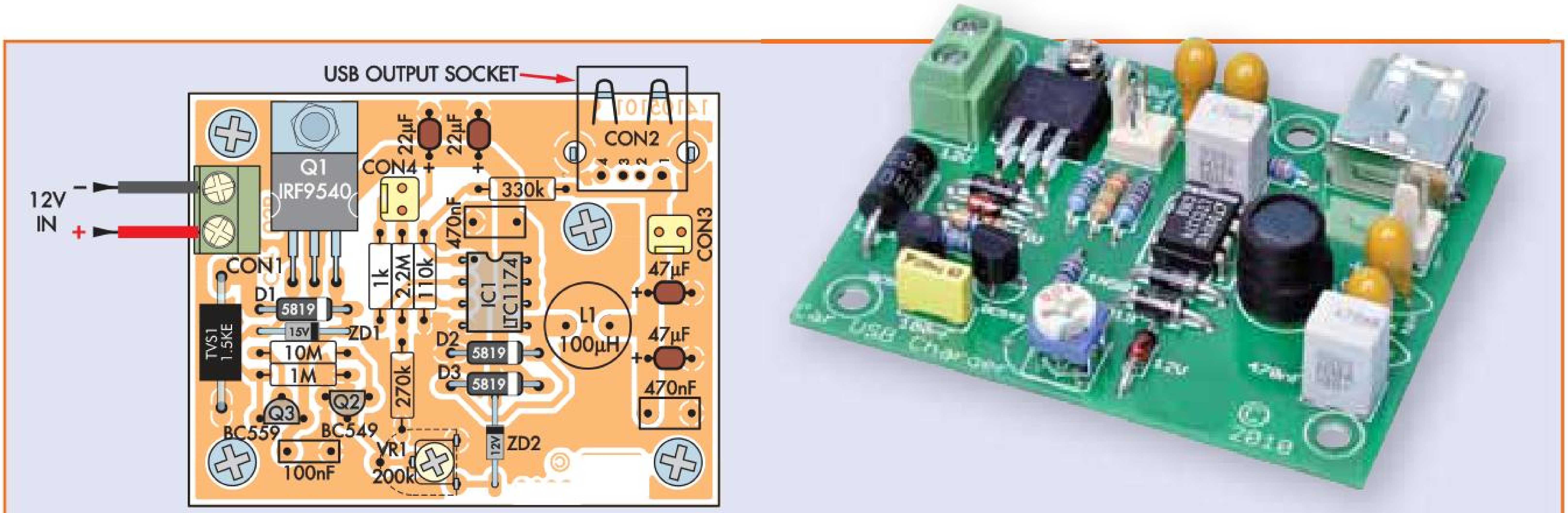


Fig.4: follow this parts layout diagram and the accompanying photo to assemble the PC board. Make sure that all polarised parts are correctly oriented and don't get the transistors mixed up.

this ground plane and any of the other copper tracks, as could occur if the board is under-etched.

If you are going to install the board in a UB5-size case, check that it fits correctly by snapping it into place. It may be necessary to file the edges slightly if it is too large. Even if it's just 0.1mm too wide, that can make the plastic case bulge slightly when it is in place.

Once you are satisfied the board is OK, install the resistors. Check each resistor with a DMM before installing it on the board, to ensure the values are correct.

Semiconductor mounting

That done, install the diodes, starting with the two Zeners (ZD1 and ZD2), then the three 1N5819 diodes (D1 to D3). Don't mix them up, and be careful with their orientation.

Next, bend the MOSFET's leads down by 90° exactly 5mm from its body and mount it on the PC board. Check that its metal tab mounting hole lines up with the board, then fasten it to the board using a 3mm machine screw from the top and a star washer and M3 nut on the underside. Do the nut up firmly, then solder and trim the leads.

Note: don't solder the MOSFET's leads first. If you do, you could stress and crack the the copper tracks on the PC board as the mounting screw is tightened. Always install the mounting screw before soldering.

Next, install the IC socket if you have decided to use one. Follow this with the transient voltage suppressor (TVS1) – its orientation doesn't matter – then install the two small-signal transistors (Q2 and Q3). Note that Q2 and Q3 are different types, so don't get them mixed up. Q2 is a BC549 *NPN* transistor, while Q3 is a BC559 *PNP* type.

If their leads are too close to fit through the holes, bend them outwards near the body of the transistor with small pliers, then back down again.

The PC-mount USB socket (CON2) is next on the list. Be sure to press it down firmly so that it sits flush against the board, then solder its two metal tabs to secure it in place. That done, solder the four pins, taking care to avoid bridging them.

Trimpot VR1 and the three MKT capacitors can now go in, followed by the four tantalum capacitors, inductor L1 (this can go in either way around) and the screw terminal block (CON1). Push the terminal block down firmly onto the board and make sure its entry holes face outwards before soldering its pins.

Be careful also with the orientation of the tantalum capacitors. A '+' will be printed on the case above the positive lead – just line it up with the '+' sign on the board overlay diagram, Fig.4.

Vibration proofing

If the unit is to be used in a vehicle, it's a good idea to apply some silicone sealant around the base of each tantalum capacitor and TO-92 transistor. The idea is to glue them to the PC board so that they can't vibrate and break their leads.

Be sure to use neutral-cure silicone sealant (the type without acetic acid).

Set-up and testing

Before soldering in the IC, it's a good idea to adjust the pre-regulator voltage. To do this, connect a power supply that can provide from 14V to 30V to the input terminal block, with an ammeter in series. It's best to start at the lower end of that voltage range.

Turn on the supply and check the current; it should be less than 1mA. If

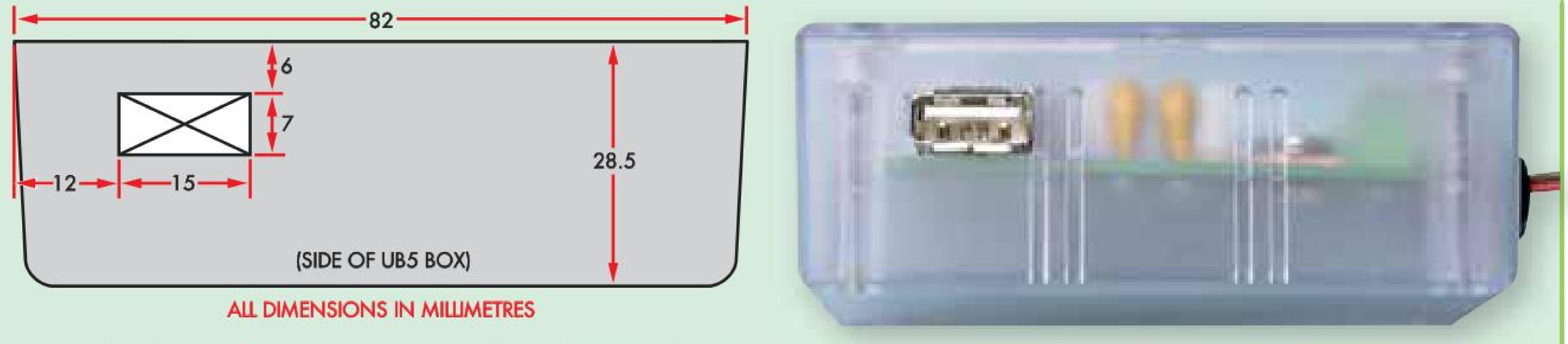


Fig.5: this diagram can be copied and used as a drilling template for the USB socket cutout in the side of the case.

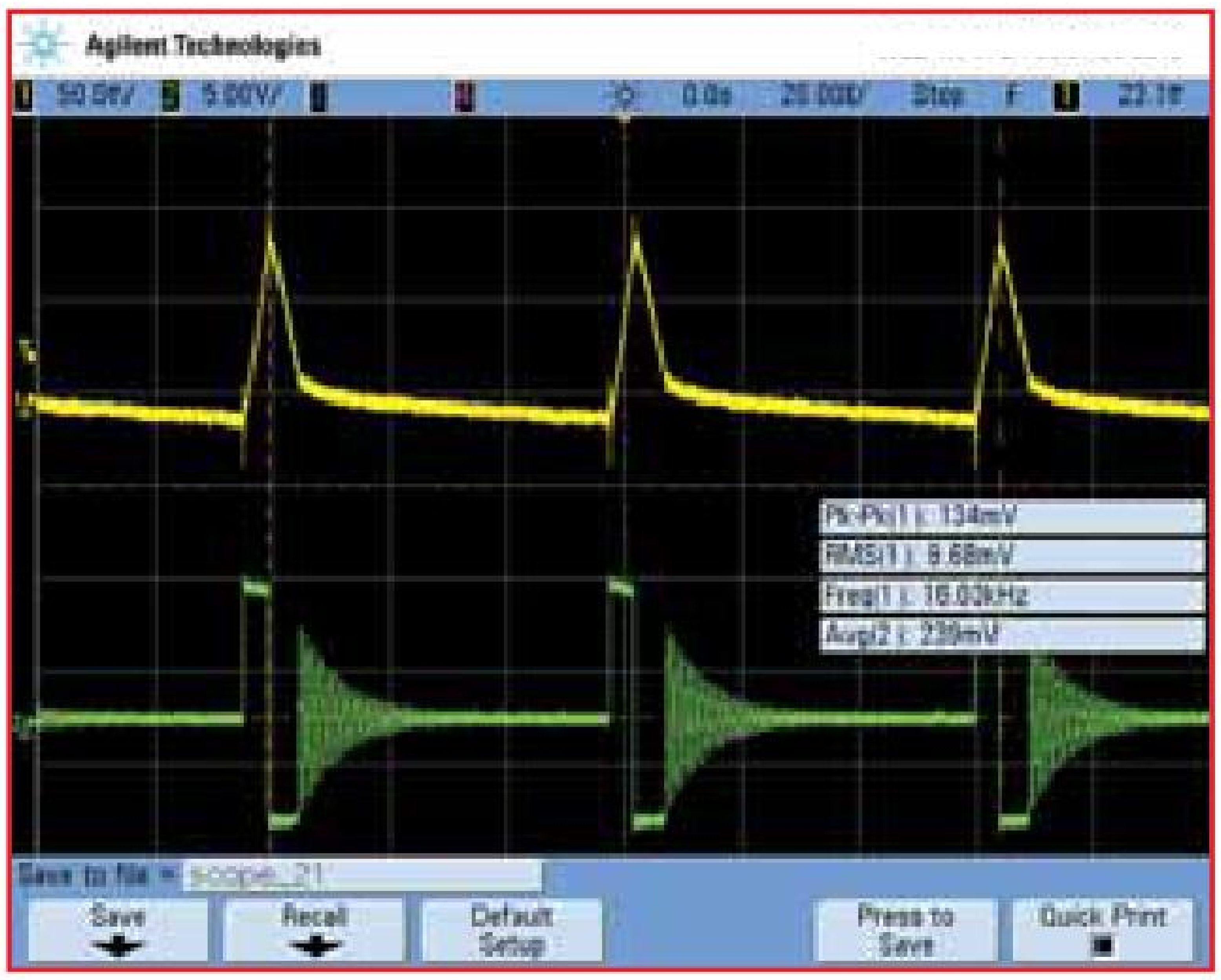


Fig.6: this shows the output voltage (yellow) and switching (green) waveforms at 10mA. The long off-time relative to the on-time can be seen. The device is operating in discontinuous mode – the inductor current falls to zero, causing the oscillations in the green trace.

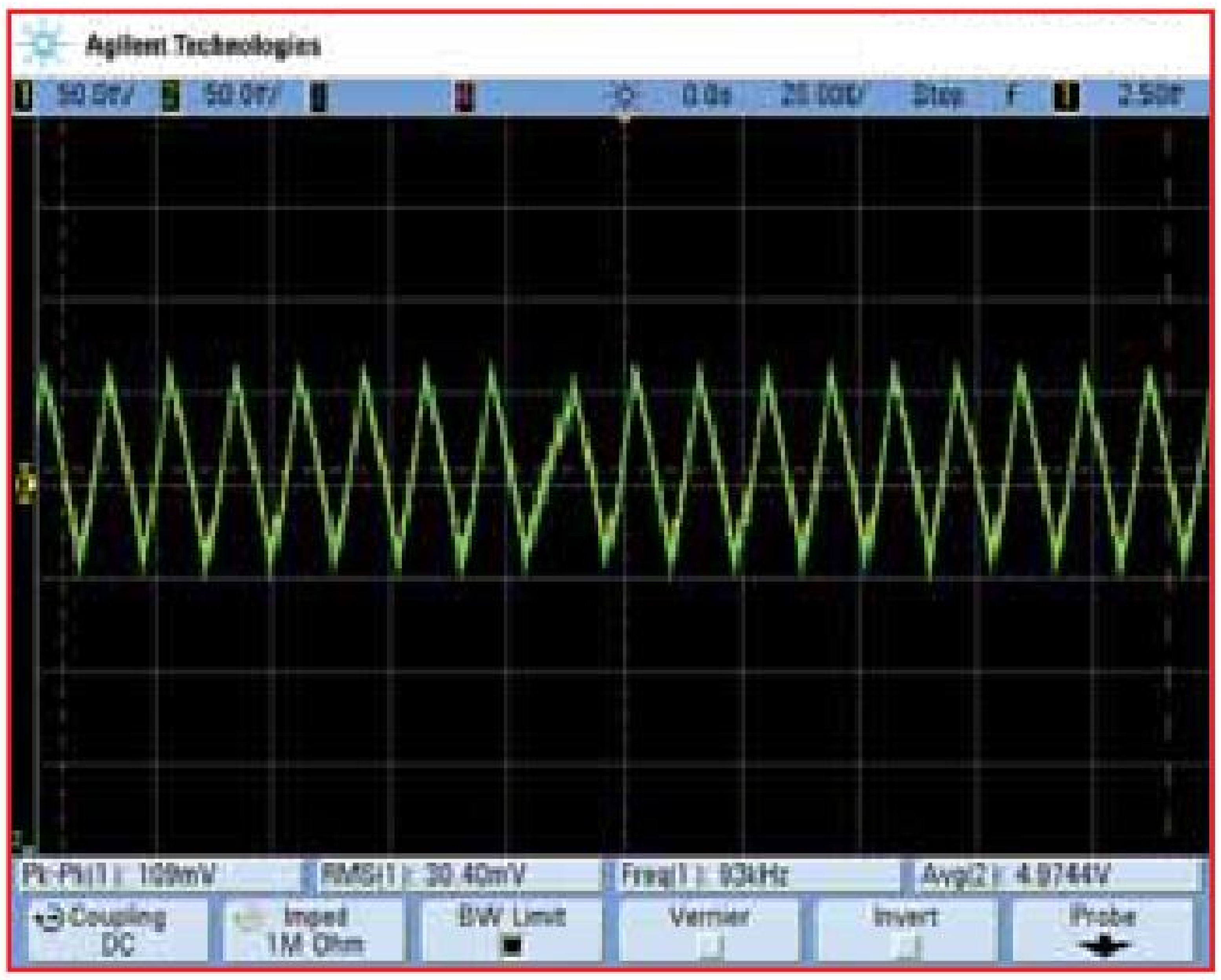


Fig.7: this scope shot shows the output voltage waveform at 450mA. The device is switching continuously and so the frequency is much higher. There is evidence of occasional burst-mode operation, as can be seen near the centre of the trace.

it is more than 1mA, then something is wrong – turn it off and check for assembly errors.

Now check the voltage between pin 8 and pin 4 for IC1. It should be in the range of 12V to 14V. Adjust trimpot VR1 until it reads 13V (or just under). If you want to be extra cautious, you can set it to 12.5V for a slight loss in efficiency.

Once the reading is correct, disconnect the power and install the IC to the PC board. Make sure it goes in the right way around.

Now power the board using a 9V to 16V supply and check the output voltage. The easiest way to do this is to check the voltage across pin header CON3.

The output should be very close to 5.0V, or if you have changed the output divider, your target voltage. It will be moving up and down slightly due to the burst mode regulation, but should not vary by more 0.2V. If it is not being properly regulated to 5V, disconnect the power and check for faults.

It's possible that the output voltage could be below 4.85V, due to a combination of the tolerance of the voltage feedback divider resistors and the tolerance of the LTC1174's internal reference voltage. If this is a case, replace the 330kΩ feedback resistor with a 360kΩ resistor. This will increase the output voltage by 6.8%, ensuring that it never drops below the minimum USB supply limit of 4.75V.

Conversely, if the output is above 5.2V, replace the 330kΩ feedback resistor with a 300kΩ resistor, to reduce the output voltage by 6.8%. However, in most cases, the output will be within 50mV of the programmed voltage with the recommended 330kΩ resistor.

Installation

If you are going to install the board in a UB5-size plastic box, you will first need to make a cutout for the USB socket. Fig.5 shows the cutting details and this diagram can be copied and used as a template. You will also have to drill a hole in one end of the box to

Recharging Apple USB Devices

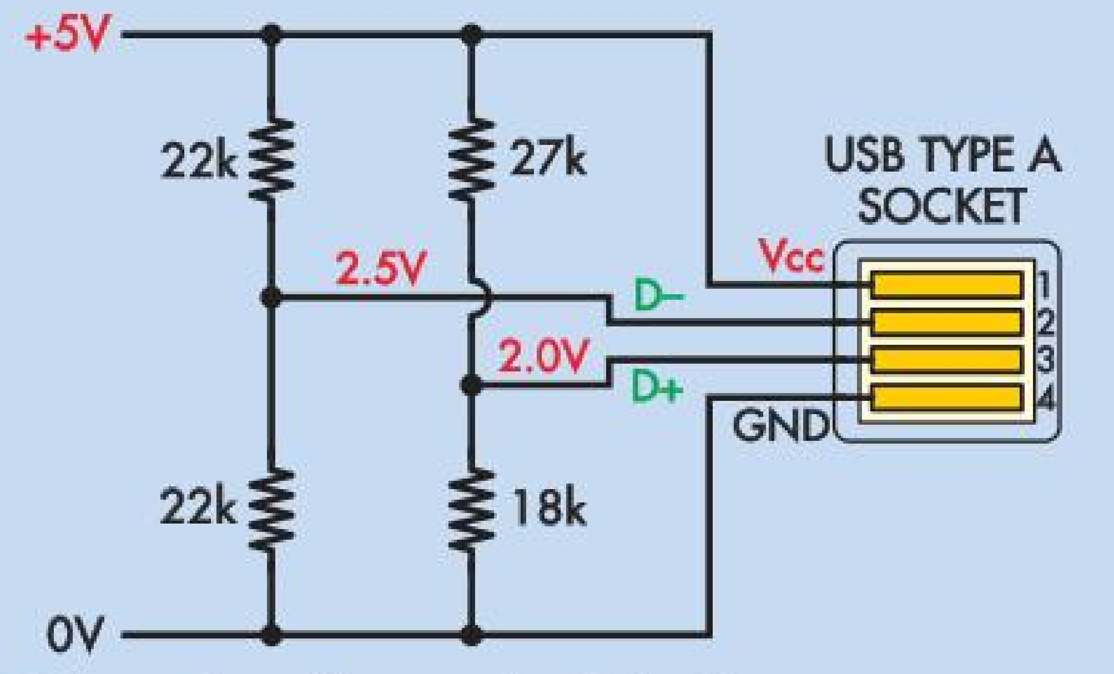


Fig.8: the data pin biasing arrangement for iPod nano 2nd generation players.

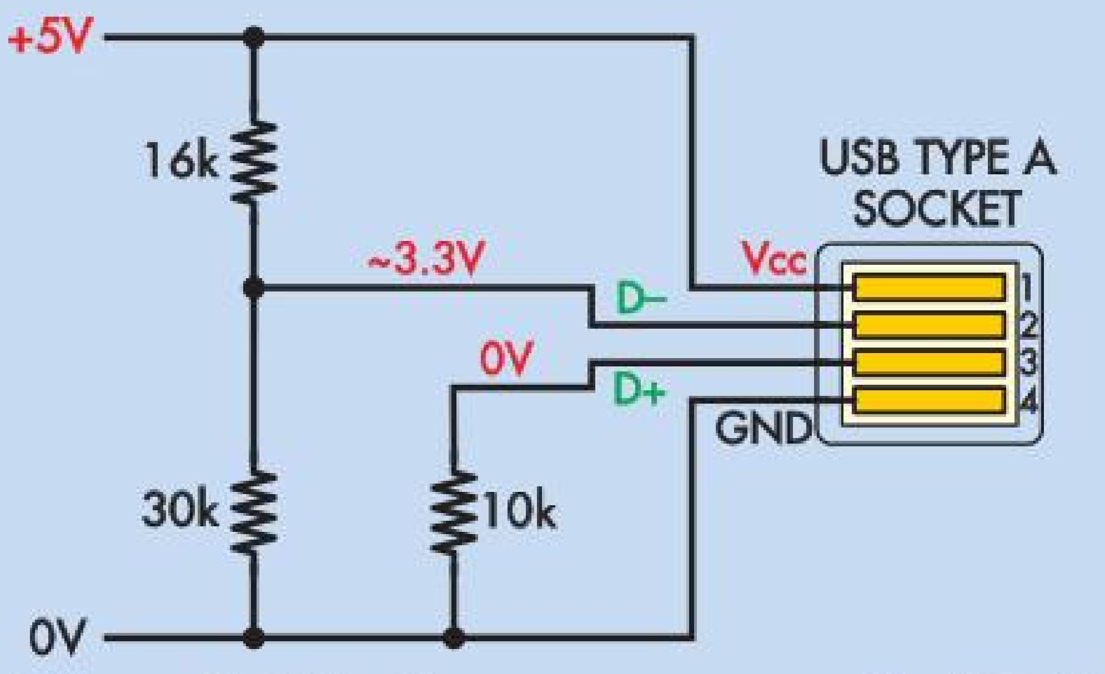


Fig.9: the biasing arrangement for iPod nano 1st generation players and 5th generation iPod video.

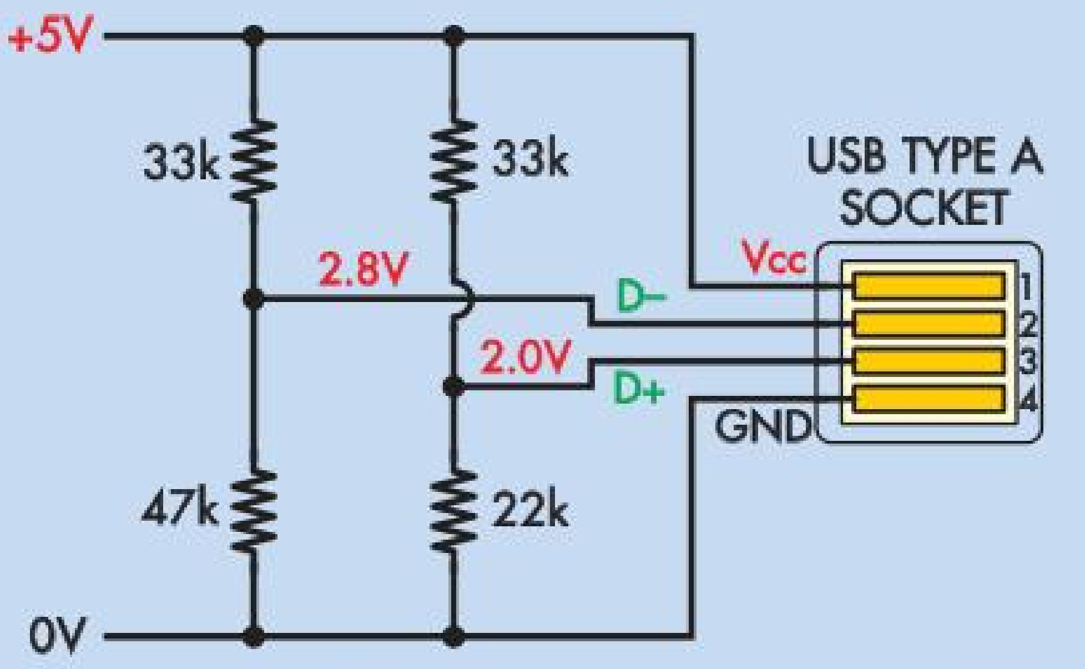
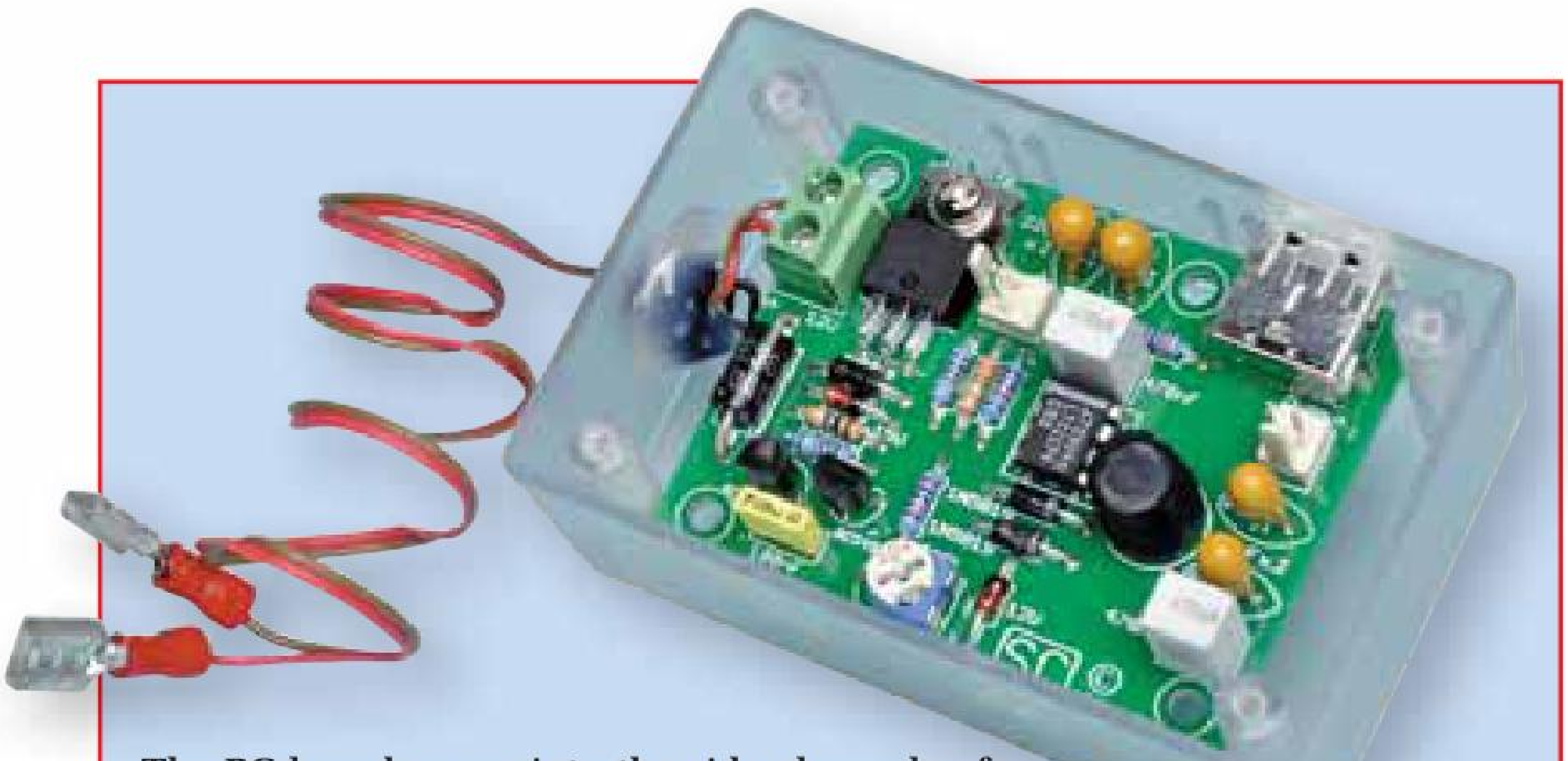


Fig.10: the biasing arrangement for the iPhone 3G and iPod touch 2nd generation player.

Some USB devices require their D+ and D– pins to be biased for charging to occur. These devices include the iPod nano 1st generation and 2nd generation music players, the 5th Generation iPod video, the iPhone 3G and the iPod touch 2nd generation player.

This biasing can be achieved using resistors, as shown in the accompanying diagrams. All resistors are 0.25W and they can be installed by adding them to the copper side of the PC board.



The PC board snaps into the side channels of a standard UB5-size plastic case. A blob of hot-melt glue can be used to stop the grommet for the input leads from working loose.

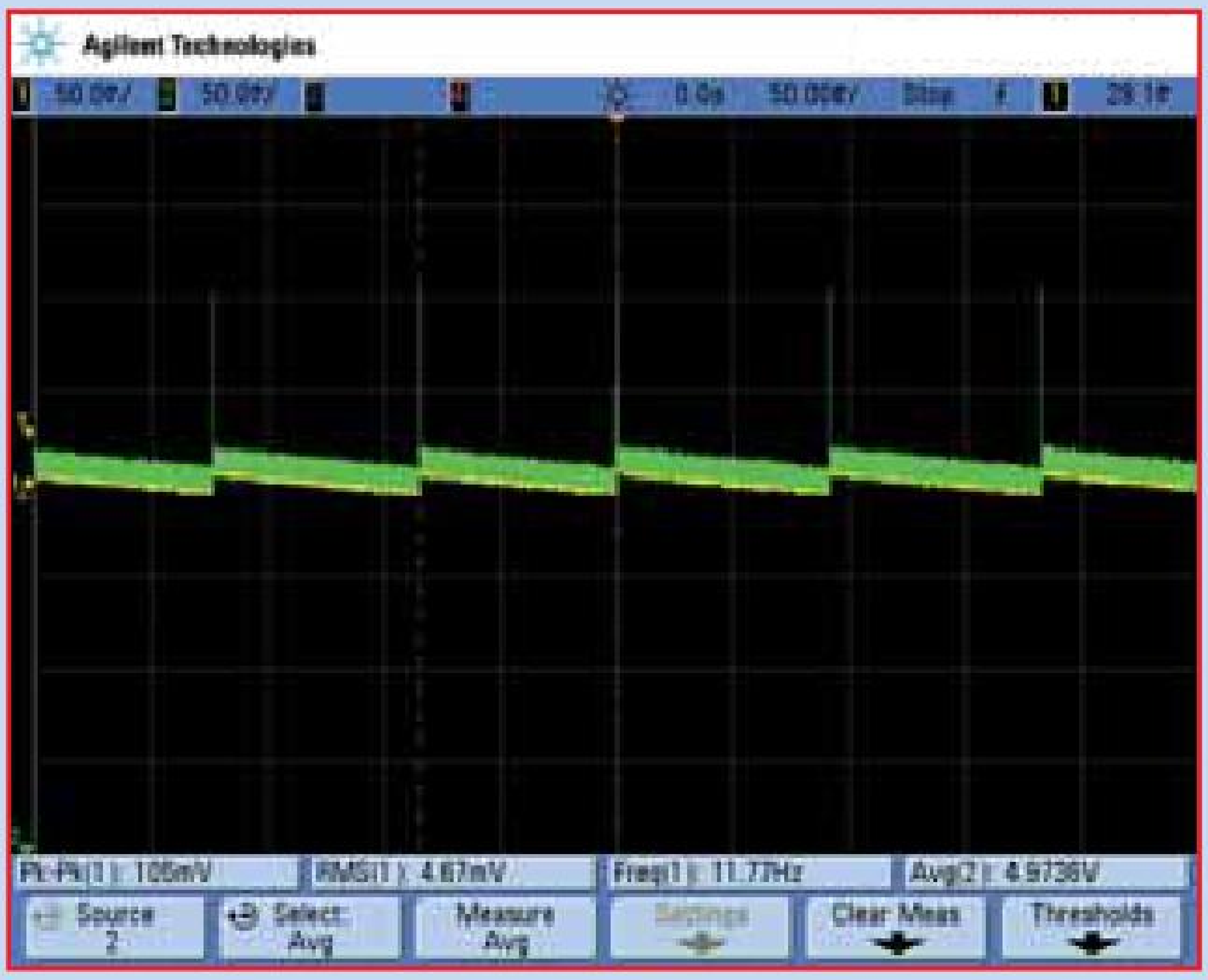


Fig.11: this shows the output voltage during standby operation. Note the low frequency of operation due to the long sleep time and burst mode.

accept a grommet for the input leads or connector.

After that, the board should simply snap into place. It's best to introduce the side with the USB socket first, and then gently push the board into place.

Alternatively, as previously stated, you can mount the board in the case of your choice and secure it on threaded standoffs using M3 × 6mm machine screws. A 500mA in-line fuse on the input side is a good idea, although the IC's current limiting should normally protect the power supply.

As a final check, once the supply is wired up, it's a good idea to use a multimeter to measure the voltage at the USB socket before attaching any devices. There are four pins in the USB socket – touch the multimeter probes to the two outer pins, being careful to avoid shorting them to adjacent pins or the surround. If the multimeter reads close to 5.0V (or your target voltage), then it's working properly.

That's it! If you are using the USB Charger to power USB devices in a vehicle, don't forget to unplug them when they are not in use, or you could still flatten the battery.

Alternatively, if you power the device via the cigarette lighter socket, it will be automatically switched off when the ignition is switched off. ***EPE***

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Need lighting away from a power source? Try this one: it's ideal for your garden, shed or even a campsite. With a 5W solar panel, a 12V SLA battery and a smart controller, it has three-stage charging for the battery and Maximum Power Point Tracking (MPPT) for the solar panel.

Part 1 – By JOHN CLARKE

NO, it's not the old joke about the bloke who invented the solar-powered torch!

Solar-powered lighting is ideal where it is impractical or unsafe to install mains-powered lighting. It can be installed just about anywhere, and best of all, running costs are zero because it uses energy from the sun.

In its simplest form, solar-powered lighting comprises a solar panel, a battery, and a lamp that can be switched on and off. But you do need to ensure that the battery is not over-charged during the day or over-discharged at night; so you need some sort of charge and discharge controller.

The block schematic of our *Solar-Powered Lighting Controller* is shown in Fig.1. The solar panel, the battery and the lamps connect to the Controller, allowing full management of charging and lighting. Additional inputs to the Controller include a light sensor to monitor the ambient light, a passive infra-red (PIR) detector and a timer.

For use in garden lighting, the light sensor allows the lights to switch on at dusk and they can remain lit for a preset period of up to eight hours, as set by the timer. Alternatively, you may wish to have the lights lit for the entire night and to switch off automatically at sunrise (subject, of course, to sufficient battery charge).

For security or pathway lighting, the lights can be set to switch on after dusk, but only when someone approaches the area. In this case, a PIR movement detector switches on the lights, while the timer switches off the lights after a predetermined period, typically about one to two minutes, but 'settable' up to the 8-hour timer limit.

For shed lighting, you may opt to switch the lights on and off using a remote pushbutton switch. They can remain on until they are switched off again or they can switch automatically after a preset period, or at sunrise.

Normally, the Controller would be set so that the lights can only come on when it is dark. However, you might want the lights on during day in a shed, and this is also possible.

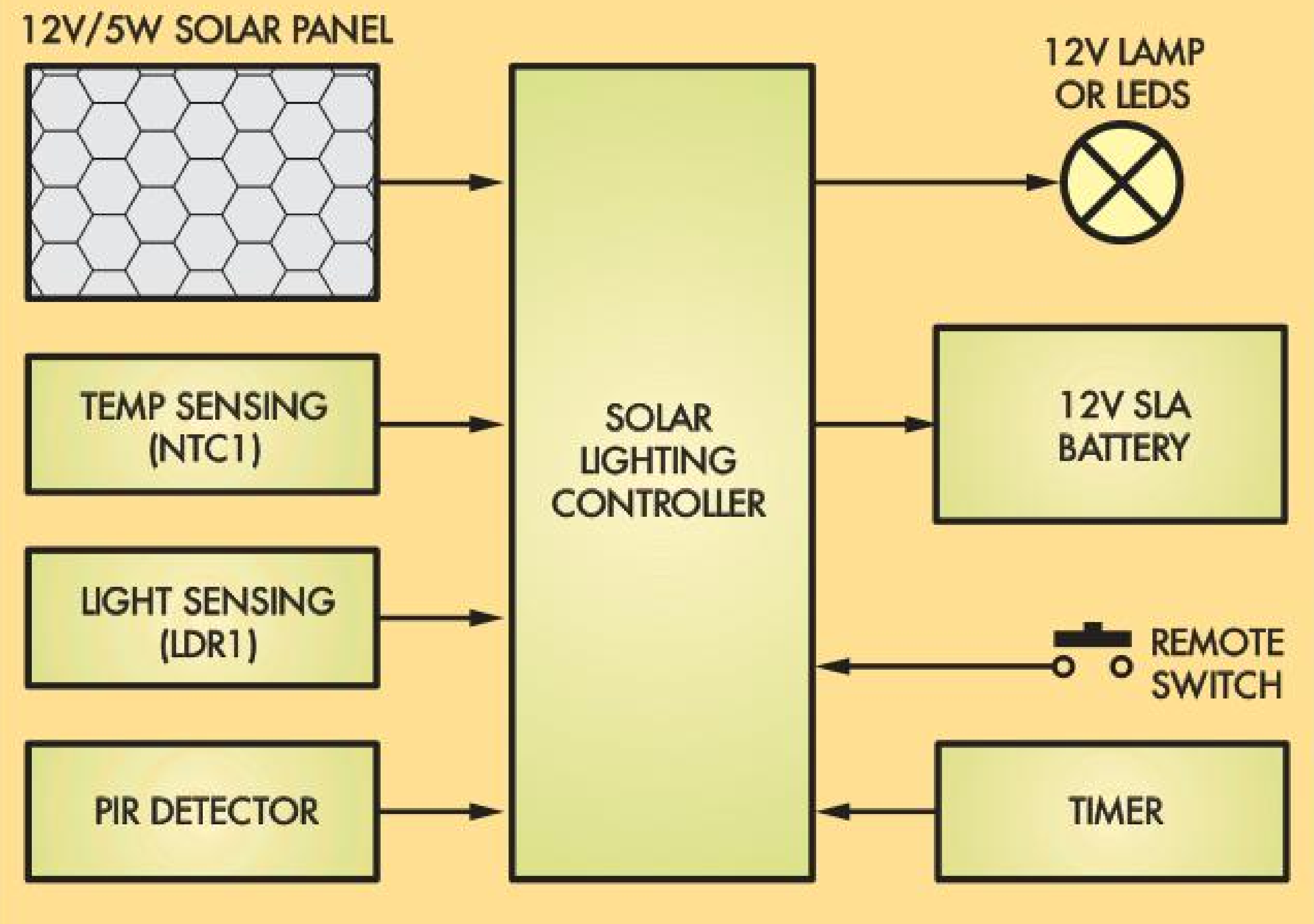


Fig.1: this shows the arrangement of our Solar Lighting Controller. The solar panel, SLA battery and the lamps connect to the Controller. Optional inputs to the controller include a light sensor to monitor the ambient light, a PIR detector and a timer.

Features

- **12V SLA battery operation**
- **Ideal for LED lighting**
- **Constant current LED driver option**
- **PIR, switch or ambient light turn-on**
- **Lamp timer included**
- **5W solar panel with 3-stage battery charging**

Table 1 shows a summary of all the lighting options, which are selected using jumper links. We'll look at these various options later.

Types of lighting

The Controller can power 12V compact fluorescent lamps (CFL), halogen lamps and 12V LED lighting. In addition, it can directly drive LEDs using a constant-current driver. Best efficiency is obtained with three 1W or 3W white LEDs in series.

The total wattage of the lights depends on the application. We recommend that the Controller be used with up to 10W of lighting, when the lights are used for a maximum of 2.5 hours each day.

Lower wattage lighting can give longer lighting periods. For example, 3W of lighting can be used for around seven hours per day.

The restriction on the lighting wattage and usage depends mainly upon the solar panels and their ability to recharge the battery each day. The specified 5W solar panel is ideally suited for recharging a partially discharged 3.3Ah battery during the day, assuming at least six hours of winter sunlight is available.

Summer time will obviously provide more hours of sunlight for charging, but then there will usually be less need to use the lights because of the reduced night period.

Lead-acid batteries (***including*** SLAs, despite popular belief to the contrary) will be seriously damaged or rendered inoperative if they are fully discharged and/or left in a discharged state. Hence, we have included low battery detection. Should the battery become discharged below 11V, the lights will switch off.

Low standby current

Standby current drain of the Solar-Powered Lighting Controller is low to conserve battery power; this has been achieved without using special components, apart from the PIR sensor. This sensor is designed for use with battery equipment where current drain is a major consideration, and is available from Altronics (Cat SX5306). We measured current drain on our sample unit at 73μA from a 12V supply. This rises to 1.3mA with movement detection, due to lighting of the internal detection indicator LED. Overall quiescent current for the Controller is 2.8mA.

Three-stage charging

The Controller charges the SLA (sealed lead-acid) battery from the solar panel in three stages, as shown in Fig.2. First

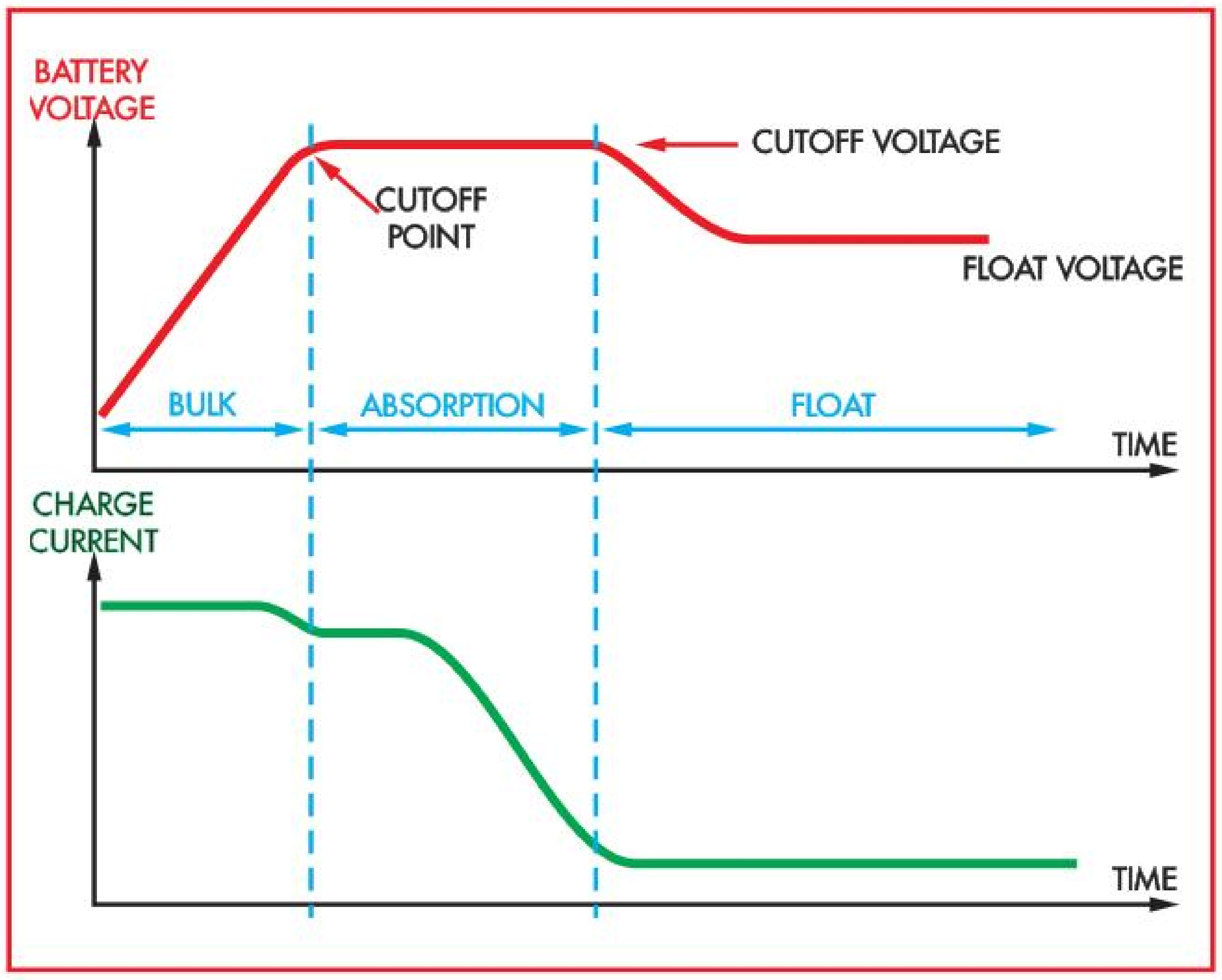


Fig.2: this shows the three charge stages. First is the initial bulk charge until the battery reaches the cutoff voltage. Then the absorption stage to fully charge the battery and then the float charge at a lower voltage to maintain charge.

is the ‘bulk charge’, applied when the battery voltage drops below 12.45V. This charge cycle applies maximum power from the solar panel until the battery voltage reaches cut-off at 14.4V, @ 20°C.

Next, is the ‘absorption’ phase, where the battery is maintained at the cut-off voltage for one hour, to ensure the battery becomes fully charged. After that, the battery is maintained on ‘float’ charge at 13.5V.

The cut-off voltage for the bulk charge and the float voltage is reduced for temperatures above 20°C, in accordance with battery manufacturers’ charging specifications. Typically, this is 19mV per °C for a 12V battery. So at 30°C, the voltages are reduced by 190mV, ie, 14.21V and 13.31V respectively.

Ambient temperature is measured using an NTC (negative temperature coefficient) thermistor located within the Controller. The monitored ambient temperature should be similar to that of the battery, provided it is located in the same area as the Controller. The thermistor can also be located adjacent to the battery, if required, for a more accurate temperature measurement of the battery.

No charging will occur if the thermistor is shorted or if it is not connected. This feature is useful when the thermistor is remotely located and the wiring could become shorted or broken. An LED indicator flashes momentarily, once every two seconds, when the thermistor is open circuit, and momentarily once per second when shorted.

Charging is also indicated using the same LED indicator. Bulk charge is indicated with the LED on continuously; it flashes on for 0.5s and 0.5s off for the absorption, and one second on, one second off during float.

A battery that has been discharged below 10.5V will be charged using short bursts of current until it reaches 10.5V, then the main charge will begin. This initial charging will be indicated by a short flash of the charge LED every four seconds.

MPPT and charge optimisation

The Controller optimises the available charge from the solar panel. As shown in Fig.3, a typical solar panel provides an output that follows the curve that ranges from maximum current when the output is shorted (I_{SC}) to maximum voltage when the output is open circuit (V_{OC}).

For the Altronics N0005 solar panel featured in this article, I_{SC} is 320mA and V_{OC} is 21.6V. Maximum power is 5.05W at 290mA and 17.4V.

When we consider the power delivered to the battery, the story becomes more interesting. If we were to connect the solar panel directly to the battery, the charge current would be about 320mA at 12V (3.84W) and about 300mA at 14.4V (4.32W). Both these values are less than the 5.05W available from the solar panel at 17.4V.

The solar panel operates at peak efficiency when it is delivering maximum power. And that is where the Maximum Power Point Tracking (MPPT) aspect of the controller comes into play.

It is essentially a switch-mode step-down power converter, which couples the available power from the solar panel to the battery with minimal power loss. At the same time, it provides three-stage charging to the battery.

How this takes place is shown in Fig.4. Current from the solar panel flows through diode D1 via Q1. When Q1 is on, current (i1) flows through inductor L1 into the 470µF capacitor and the battery. The inductor magnetic field grows (ie, current rises to its maximum value) and after a short period, Q1 is switched off and the stored energy in L1 maintains current flow (i2) via diode D2.

The ratio of the on to off period (duty cycle) for Q1 is controlled so that the solar panel delivers its maximum power. The solar panel is not required to supply the peak current into the inductor, as this is drawn from the 470µF reservoir capacitor, C1. Similarly, capacitor C2 acts as a reservoir to charge the battery when current is not flowing through the inductor. Incidentally, these capacitors are low ESR (effective series resistance) types, suited to the switching frequency of 31.24kHz.

The voltage from the solar panel is monitored by op amp IC2a, while the current is monitored by measuring the voltage across a 0.1Ω resistor. This voltage is multiplied by –50 in op amp IC2b. Both op amps feed their signals to microcontroller IC1, which controls the whole circuit.

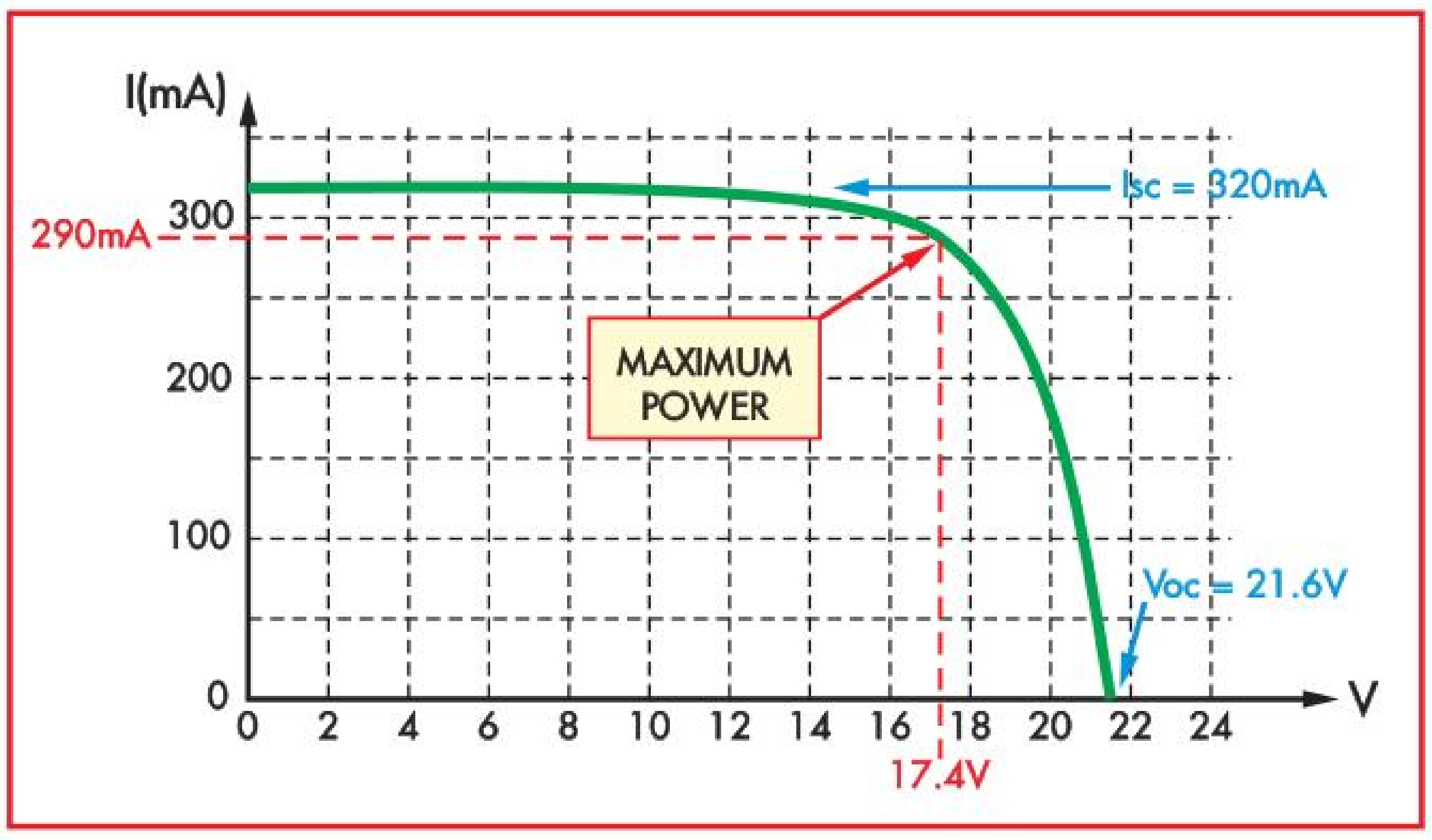
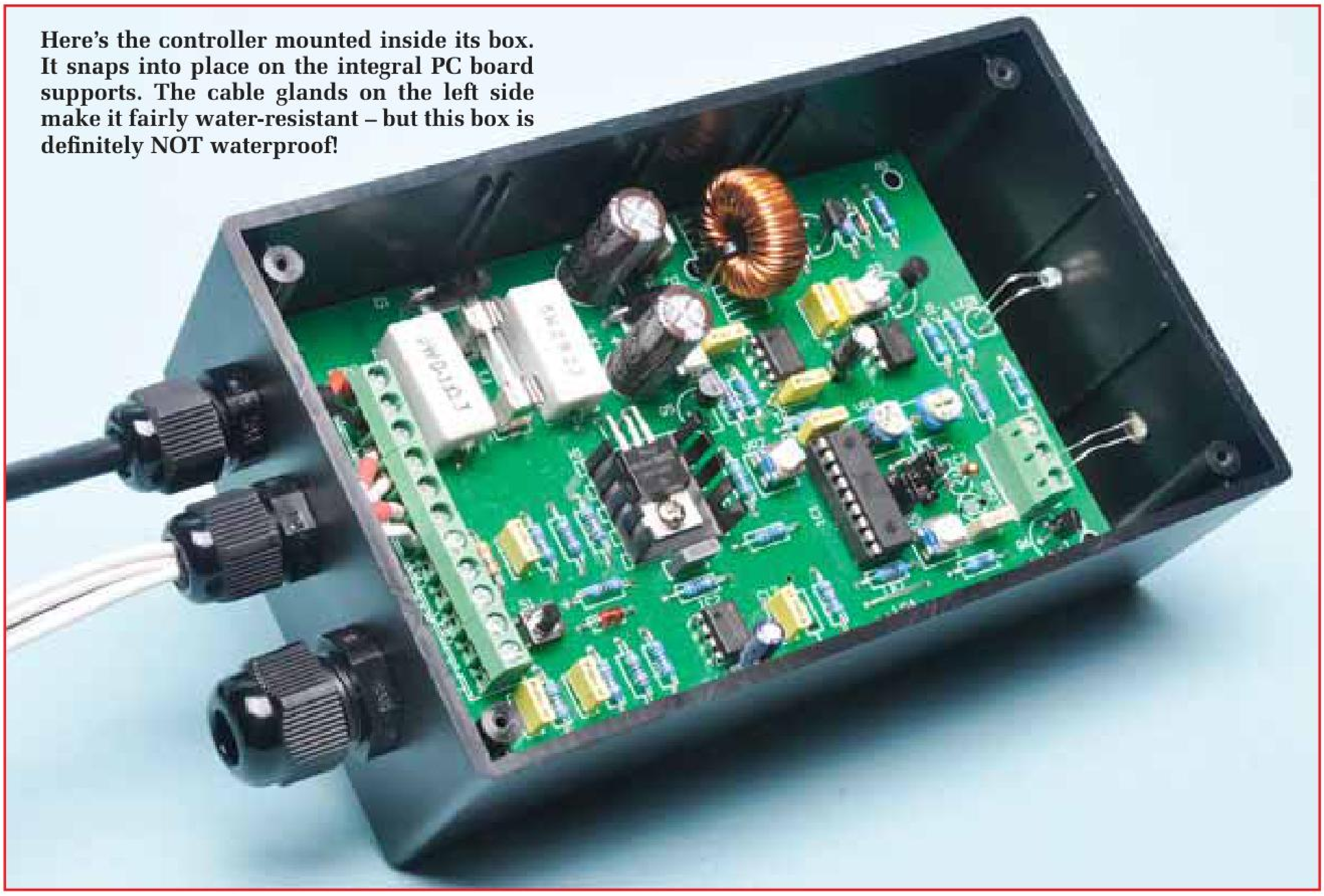


Fig.3: the solar panel provides an output that follows this curve, ranging from maximum current when the output is shorted (Isc) to maximum voltage when the output is open circuit (Voc). For best efficiency, it is necessary to operate the solar panel at its maximum power point.



Here's the controller mounted inside its box. It snaps into place on the integral PC board supports. The cable glands on the left side make it fairly water-resistant – but this box is definitely NOT waterproof!

Circuit details

The full circuit diagram for the *Solar-Powered Lighting Controller* is shown in Fig.5 and is based around a PIC16F88 microcontroller, IC1. It monitors IC2, the PIR sensor, switch S1, light-dependent resistor LDR1 (for day/night sensing), the NTC thermistor and also controls lamp operation via MOSFET Q4.

For operation using the Altronics SX5306 PIR detector, output from the PIR is normally at 0V, but when it detects movement, the trigger output goes high to 4.5V. Output impedance of this PIR is high, at about 700kΩ, so it cannot provide much current before the voltage drops significantly. Hence, the input loading for this sensor signal is 10MΩ.

Note that resistor R2 is not used with the SX5306 PIR sensor. R2 is included if a standard PIR detector is used. Many standard PIR detectors include a relay with normally-closed contact that opens when movement is detected. With R2 included, this provides a pull-up to 5V when the contact opens.

A 12V power supply for either type of PIR detector is included.

A pushbutton switch (S1) is monitored by the RB1 input (IC1 pin 7), normally held high at 5V with a 10kΩ pull-up resistor. Pressing the switch pulls the RB1 input low. Switch S1 is included on the Controller PC board for test

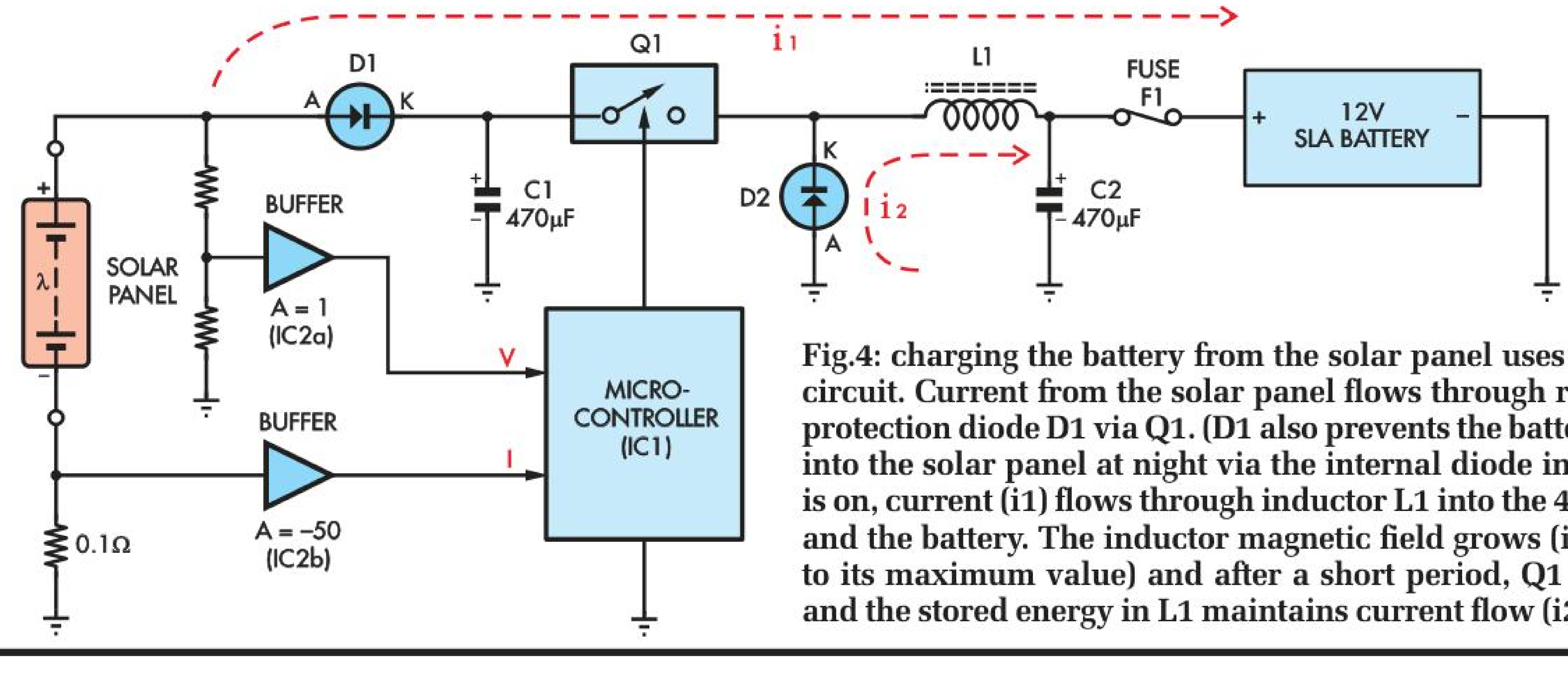


Fig.4: charging the battery from the solar panel uses a switch-mode circuit. Current from the solar panel flows through reverse-polarity protection diode D1 via Q1. (D1 also prevents the battery discharging into the solar panel at night via the internal diode in Q1). When Q1 is on, current (i1) flows through inductor L1 into the 470µF capacitor and the battery. The inductor magnetic field grows (ie, current rises to its maximum value) and after a short period, Q1 is switched off and the stored energy in L1 maintains current flow (i2) via diode D2.

purposes, but an external on/off (pushbutton) switch can be connected as well. The 100nF capacitor at RB1 prevents interference when long leads are used to an external switch.

Ambient light is monitored using the light dependent resistor (LDR1) at the AN5 analogue input of IC1 (pin 12). The LDR forms a voltage divider with the series-connected 100kΩ resistor and VR5 connecting to the 5V supply. In normal daylight, the LDR has a low resistance (about 10kΩ), but this rises to over 1MΩ in darkness. Therefore, the voltage at the AN5 input will be relative to the ambient light. If the voltage across LDR1 is below 2.5V, IC1 determines it is daylight; above 2.5V it reads it as dark.

This measurement is made when MOSFET Q6 is switched on, tying the lower end of the LDR close to 0V. VR5 allows threshold adjustment of the LDR sensitivity.

Link options

There are three options available for turning on the LED/light: (1) only at night, (2) only in daylight, or (3) either. The position of link LK1 selects the first two options, while the third option operates with the link in the 'night' position, but has the LDR left out of circuit.

The lamp can be switched on using the pushbutton switch S1 (internal or external), provided the ambient light level is correct according to the selection made with LK1.

When link LK2 is in the PIR position, the lamp can also be switched on when the PIR detects movement; again dependent on ambient light, according to the LK1 selection.

If PIR operation is selected with LK2, but the PIR detector is not connected to the circuit, then the lamp can only be switched on with S1.

If LK2 is set to the LDR position, the PIR does not switch on the lamp – the lamp is switched on at the change of ambient light, day to night or night to day (again, dependent on link LK1).

Built-in timer

The lamp can also be switched off with a timer, or ambient light. The various options are summarised in Table 1.

The lamp 'on' period is adjustable using trimpot VR4, which connects between 5V and the drain (D) of Q6. When Q6 is switched on, trimpot VR4 is effectively connected across the 5V supply. The wiper voltage is monitored at the AN0 input of IC1 (pin 17). We'll cover the procedure to set VR4 later.

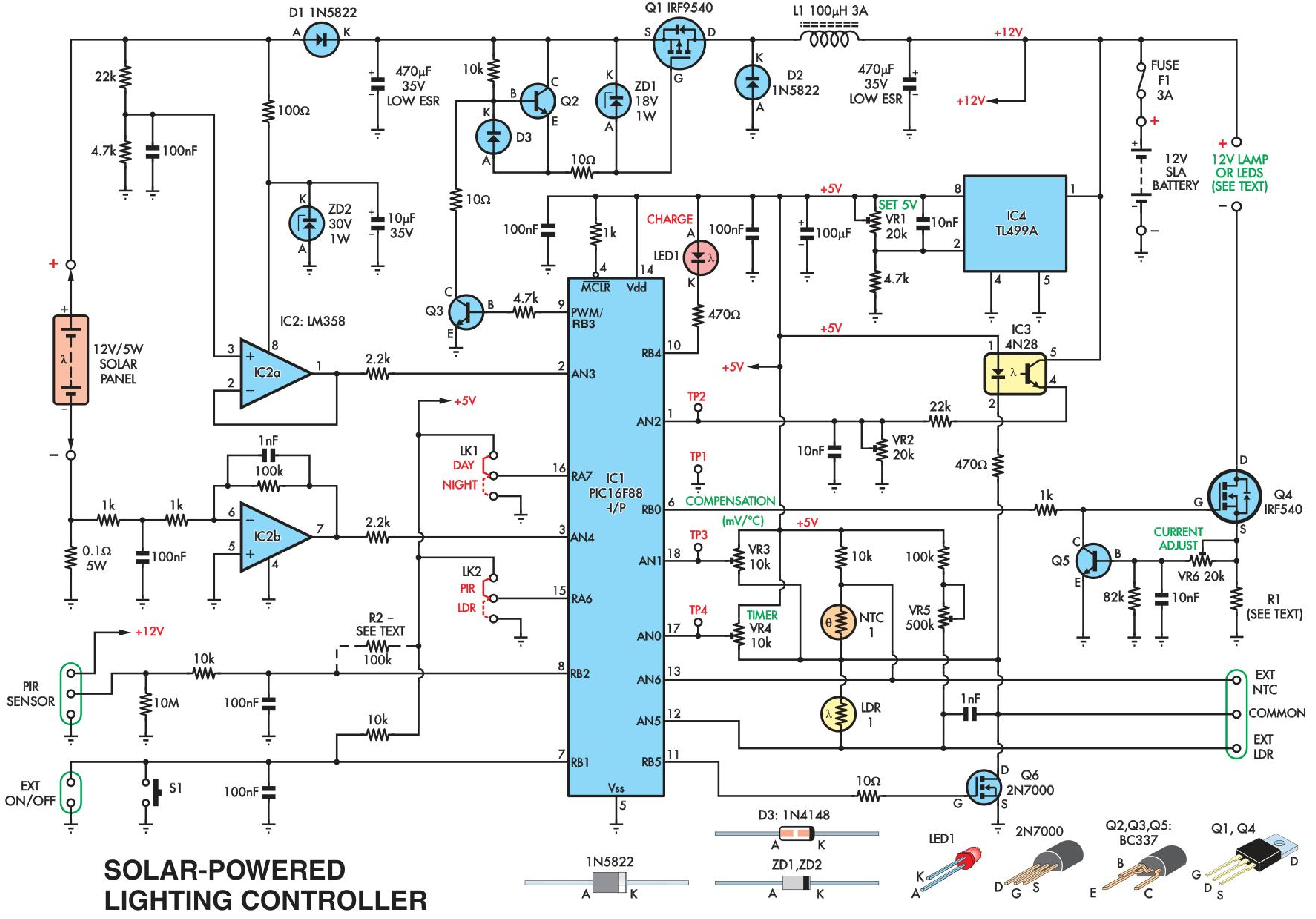
Lamp driver

The Controller includes a constant current lamp driver, which can power LEDs or standard 12V incandescent lamps. Current control is important for LEDs, because with voltage control, small variations in the supply voltage can result in large changes in the current flow.

MOSFET Q4 and its associated components form an active current sink. Q4's transconductance is varied in response to the voltage developed across resistor R1, which is proportional to the lamp current.

Specifications

Lamp driver	Constant current LED drive
Lamp current	Typically less than 350mA for 1W LEDs or less than 1A for 3W LEDs, or at 2A for 12V halogen and 12V LED lamps
Lamp timer	2s to 8h, see Table 3 (next month)
LED driver	Up to three white LEDs in series; 1W or 3W types
Lamp switch on	Via ambient light change, PIR sensor and switch
Lamp Switch off	Via ambient light change, timer or switch
Low battery lamp off voltage	11V
Quiescent current	2.8mA
Charging voltage	14.4V at 20°C for main bulk charge and absorption cut-off voltage; float is 13.5V @ 20°C
Compensation.	Adjustable from 0 to 50mV per °C, reducing charge voltage above 20°C and increasing below 20°C; no increase below 0°C.
Thermistor warning	Open or short circuit (Charge LED flashes 262ms every 2s for open circuit, and 262ms every 1s for short circuit)
Low battery charge	At less than 10.5V charging via a 6.25% duty cycle charge burst (Charge indicator flashes 260ms each 4.2s)
Bulk charge initiation	When battery drops below 12.45V or the equivalent of 75% charge
Charge LED indicator	Bulk charge: Continuously lit Absorption: flashing at 0.5s on, 0.5s off Float: 1s on and 1s off
Charger	Charging can start when solar panel is >12V
Charger operation	Switch-mode power converter at 31.24kHz maintains solar panel operation at maximum power output.


D1 1N5822
A K
Q1 IRF9540
S D G
L1 100µH 3A
+12V
22k
100Ω
470µF 35V LOW ESR
10k
B C E
Q2
K A
ZD1 18V 1W
D2 1N5822
470µF 35V LOW ESR
+12V
FUSE F1 3A
+
12V SLA BATTERY
–
+
12V LAMP OR LEDS (SEE TEXT)
–
4.7k
100nF
D3
10Ω
10Ω
ZD2 30V 1W
10µF 35V
100nF
1k
CHARGE
LED1
100nF
+5V
100µF
SET 5V
VR1 20k
10nF
4.7k
IC4 TL499A
8 1 2 4 5
+
12V/5W SOLAR PANEL
–
IC2: LM358
IC2a
3 2 8 1
2.2k
Q3
4.7k
MCLR
Vdd
PWM/ RB3
AN3
RB4
470Ω
+5V
+5V
IC3 4N28
1 2 4 5
+5V
LK1
DAY
NIGHT
RA7
IC1 PIC16F88 -I/P
AN2
TP2
22k
10nF
VR2 20k
470Ω
TP1
1nF
100k
1k
1k
0.1Ω 5W
100nF
IC2b
6 5 7 4
2.2k
AN4
RB0
COMPENSATION (mV/°C)
TP3
VR3 10k
+5V
10k
100k
1k
G
Q4 IRF540
D S
CURRENT ADJUST
VR6 20k
Q5
82k
10nF
R1 (SEE TEXT)
LK2
PIR
LDR
RA6
AN1
TP4
TIMER VR4 10k
AN0
NTC 1
VR5 500k
+12V
R2 – SEE TEXT 100k
PIR SENSOR
10k
10M
100nF
RB2
AN6
AN5
LDR 1
1nF
EXT NTC
COMMON
EXT LDR
10k
EXT ON/OFF
S1
100nF
RB1
RB5
Vss
10Ω
Q6 2N7000
D3: 1N4148
1N5822
ZD1,ZD2
LED1
2N7000
Q2,Q3,Q5: BC337
Q1, Q4

SOLAR-POWERED LIGHTING CONTROLLER

Fig.5: the circuit is based around a PIC16F88 microcontroller, IC1. It monitors IC2, the PIR sensor, switch S1, light-dependent resistor LDR1 (for day/night sensing), the NTC thermistor and also controls lamp operation via MOSFET Q4.

Table 1: Lamp operation

PIR (LK1)	LDR (LK2)	Lamp ON	Lamp OFF
In	Night	PIR movement detection or with S1 during night time only	Timer timeout, S1 or at dawn
In	Day	PIR movement detection or with S1 during day time only	Timer timeout, S1 or at dusk
In	Night (LDR1 disconnected)	PIR movement detection or with S1 during day and night	Timer timeout or S1
Out	Night	Day-to-night transition or with S1, night only	Timer timeout, S1 or automatically at dawn
Out	Day	Night-to-day transition or with S1, day only	Timer timeout, S1 or automatically at dusk
Out	Night (LDR1 disconnected)	S1 during day or night	Timer timeout or S1

IC1's RB0 output at pin 6 switches on the lamp by applying 5V to Q4's gate, allowing current to flow from its drain (D) to source (S). If the current through R1 rises enough for the voltage across it to exceed 0.6V, transistor Q5 turns on and reduces Q4's gate voltage. This reduces the current flow. A steady state arises so that the voltage across R1 is kept at approximately 0.6V.

If R1 is 2.2Ω, about 270mA will flow through Q4 and the lamp. Trimpot VR6, in combination with the 82kΩ resistor, acts as a voltage divider, allowing the current flow to be adjusted upwards. If VR6 is set for maximum resistance, then the voltage across R1 will be 0.76V before Q5 turns on, allowing up to 345mA through the lamp.

The value of 2.2Ω for R1 is suitable for a lamp consisting of three 1W white LEDs in series. Their combined forward voltage is about 10.5V. With 0.76V across R1, this means that there will be 0.74V across Q4 (its minimum drop is around 0.1V in this case). With this setup, the lamp driver consumes some 0.51W (1.5V × 340mA) and the LEDs consume a total of 3.57W. Thus, efficiency is about 87%.

If the 270mA to 340mA range is inadequate, then R1's value can be changed. For 3W star LEDs, use 0.68Ω, which results in a range of 0.9A to 1.1A. For standard 12V lamps, the current regulator serves as short-circuit protection – a 0.33Ω resistor allows up to 2A before limiting occurs.

Charging

For charging, we use the switch-mode step-down circuit previously described in Fig.4. MOSFET Q1 is a *P*-channel type that switches on with a gate (G) voltage that is negative with respect to the source (S). The voltage at Q1's source (from the solar panel and diode D1) can range up to about 21V when the solar panel is not delivering current.

The gate is pulled negative with respect to the source via transistor Q3, a 10Ω resistor and diode D3. Transistor Q3 is pulse-width-modulated by the RB3 output of IC1 (pin 9) via a 4.7kΩ resistor.

When RB3 goes to 5V, Q3 is switched on and pulls the gate of Q1 low. The MOSFET is therefore switched on.

Transistor Q2 is held off due to its base being held lower than the emitter via the forward-biased diode D3.

The 10Ω resistor at the collector of Q3 limits initial Zener diode current through ZD1 in the event that the gate voltage exceeds 18V. This Zener protects Q1's gate from breakdown due to excessive gate voltage. With extreme over voltage, transistor Q3 will come out of saturation, preventing little more than about 20mA current through the 18V Zener diode.

When the output of RB3 is taken to 0V, transistor Q3 switches off, and the base of Q2 is pulled to the Q1 source voltage via a 10kΩ resistor. Transistor Q2 switches on and pulls the gate of Q1 to the source and so switches off Q1. The switch-on and switch-off action for Q1, as controlled by the RB3 output of IC1 is at 31.24kHz.

Battery voltage monitoring

Battery voltage is monitored at IC1's AN2 input via optocoupler IC3 and a resistive divider comprising a 22kΩ resistor and 20kΩ trimpot, VR2. This divider, or more properly the trimpot, is adjusted so that the voltage appearing at AN2 is actually 0.3125 times the battery voltage.

The reason for this is so that the 5V limit of analogue input AN2 is not exceeded – for example, a 15V battery voltage will be converted to just 4.69V. We'll cover this procedure in the setup later.

The resistive divider is not directly connected to the battery, but via the 'transistor' within optocoupler IC3, which connects the battery voltage to the divider whenever the LED within IC3 is on. The voltage between the collector and emitter of the transistor has a minimal effect on the battery voltage measurement, as it is only around 200µV.

The divided voltage is converted to a digital value by the IC's firmware.

The optocoupler LED is driven from the 5V supply through a 470Ω resistor and to 0V when MOSFET Q6 is switched on. The thermistor (NTC1) forms a voltage divider with a 10kΩ resistor across the supply when Q6 is switched on. The AN6 input to IC1 (pin 1) monitors this voltage and converts it to a value in degrees Celsius.

At the same time, IC1's AN1 input (pin 18) monitors the setting of trimpot VR3, which is also effectively connected across the 5V supply when Q6 is switched on. The AN6 and AN1 inputs are converted to a mV/°C value, which can range from 0mV/°C when VR3 is set to 0V, to 50mV/°C when VR3 is set for 5V.

Power saving

As we just mentioned, MOSFET Q6 connects trimpots VR3 and VR4, the LDR and the NTC to 0V, and also powers the optocoupler LED. Q6 is powered on with a 5V signal from the RB5 output of IC1 (pin 11). The MOSFET then momentarily connects these sensors to 0V, so the IC1 microcontroller can measure their values. When Q6 is off, these trimpots, sensors and battery divider are disconnected from the supply to conserve the power drain from the battery.

Parts List – Solar-Powered Lighting Controller

1 PC board coded 845, available from the *EPE PCB Service*, size 133mm × 86mm
1 UB1-size plastic box 157mm × 95mm × 53mm
4 3-way PC mount screw terminals 5.08mm pin spacing (CON1,CON2)
1 2-way PC mount screw terminals 5.08mm pin spacing (CON1)
1 100µH 3A Choke (Jaycar LF1272 or equivalent)
1 SPST PC mount tactile membrane switch with 3.5 or 4.3mm actuator (S1)
1 10kΩ NTC thermistor (Altronics R4290, Jaycar RN3440 or equivalent)
1 LDR with 10kΩ light resistance, 1MΩ dark resistance (Jaycar RD3480 or equivalent)
4 IP68 cable glands for 6mm cable
2 4.8mm female spade crimp connectors
1 DIP18-pin IC socket
2 M205 PC mount fuse clips
1 3A M205 fast-blow fuse
1 TO-220 U-shaped heatsink 19mm × 19mm × 10mm
1 M3 × 10mm screw, nut and washer
2 PC stakes (TP1,TP2)
1 2-way pin header with 2.54mm pin spacing (TP3,TP4)
2 3-way pin headers with 2.54mm pin spacings (LK1, LK2)
2 jumper shunts for pin headers
1 100mm cable tie
1 100mm length of 0.7mm tinned copper wire or 4 0Ω links

Semiconductors
1 PIC16F88-I/P programmed microcontroller (IC1)
1 LM358 dual op amp (IC2)
1 4N28 optocoupler (IC3)
1 TL499A regulator (IC4)
1 IRF9540 *P*-channel MOSFET (Q1)
3 BC337 *NPN* transistors (Q2,Q3,Q5)
1 2N7000 *N*-channel MOSFET (Q6)
1 IRF540 *N*-channel MOSFET (Q4)
2 1N5822 3A Schottky diodes (D1,D2)
1 1N4148 switching diode (D3)
1 18V 1W Zener diode (ZD1)
1 30V 1W Zener diode (ZD2)
1 3mm high intensity red LED (LED1)

Capacitors
2 470µF 35V (or 50V) low ESR
1 100µF 16V
1 10µF 35V
6 100nF MKT polyester
3 10nF MKT polyester
2 1nF MKT polyester

Resistors (0.25W 1%)
1 10MΩ 5%
4 10kΩ
2 470Ω
2 100kΩ
3 4.7kΩ
1 100Ω
1 82kΩ
2 2.2kΩ
3 10Ω
2 22kΩ
4 1kΩ

Resistors (5W)
1 0.1Ω
1 0.33Ω – 3.3Ω (value selected from Table 2 – next month)

Mini horizontal trimpots (5.08mm pin spacings)
2 10kΩ (VR3,VR4)
3 20kΩ (VR1,VR2,VR6)
1 500kΩ (VR5)

Miscellaneous
1 12V 3.3AH SLA battery
1 12V 5W solar panel array (Altronics N0005 or N0704, Jaycar ZM9091 or ZM9026 or equivalent)
Figure-8 wire, solder, 4-way alarm cable.

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Software

All software program files for the *Solar-Powered Lighting Controller* will be available from the *EPE* website at **www.epemag.com**.

WE DO NOT SUPPLY READY-PROGRAMMED MICROCONTROLLERS

Additional Parts (as required)

1 Altronics low current PIR movement detector (IR-TEC IR-530LC) (Altronics SX5306)
or
1 PIR movement detector with NC relay contacts (preferably with 1mA or less standby current – will also need R2, an extra 100kΩ resistor)

LEDs
1W white LEDs (Jaycar ZD0424, ZD0426, ZD0508, ZD0510) (Altronics Z0251, Z0252A)
3W white LEDs (Jaycar ZD0532, ZD0534, ZD0442, ZD0-0444) (Altronics Z0258A, 0259A

LED drivers (see text; Controller has LED driver built in)
Jaycar AA0592, Altronics M3310 for 1-6 LEDs at 1W
Jaycar AA0594 for 1-6 LEDs at 3W (Altronics M3320 for 1-3 LEDs at 3W)

12V lamps
IP67 3-LED modules (eg, Jaycar ZD0490)
MR16 lamps (eg, Jaycar ZD-0346-ZD0349)
10W Halogen (eg, Altronics Z2400)
12V DC LED Globes (eg, Altronics X2150)

Internal (above) and external shots of our 3-LED light, which is perfect for this controller. You can just see the blurry LEDs through the translucent lid in the photo below. Construction details will follow next month.

One problem with using Q6 to make the 0V connection for the trimpots, battery and sensors is that these sampled voltages cannot be measured easily with a multimeter. This is because a multimeter will not be fast enough to capture the voltage as Q6 switches on momentarily. And we do need to measure some of these voltages for setting up.

For example, we need to be able to set VR2 so that the battery divider is correct, and to measure the timer and mV/°C values set with VR4 and VR3. In order make these measurements; Q6 is switched whenever S1 is pressed.

Other power saving methods includes how the charge LED (LED1) is driven. It is only used to show charging when there is supply available from the solar panel. Current to drive the LED is therefore provided from the solar panel instead of the battery. The only time this LED will light using battery power is if the thermistor is open or short circuit. In these cases, the LED flashes these indications at a low duty cycle, again conserving power.

Op amp IC2 is also powered from the solar panel itself. This arrangement is suitable because we only want to measure the solar panel voltage and its current whenever the solar panels are generating power.

Power for IC2 is derived from the solar panel via a 100Ω series resistor. A 30V Zener diode limits transient voltages that could occur in long wiring that connects between the controller and the solar panel. Diode D1 prevents the battery from powering IC2 via Q1's internal diode and L1.

Solar panel monitoring

Solar panel voltage is monitored using a 22kΩ and 4.7kΩ voltage divider. A 100nF capacitor filters any transient voltages or noise that could be induced through long leads from the solar panel. The voltage is buffered by IC2a and the output is applied to the AN3 input of IC1. The voltage divider ratio allows for measurement of up to about 28V from the solar panel. Should IC2a's output go above 5V, the 2.2kΩ resistor limits current into IC1.

Current through the solar panel is measured by the voltage developed across a 0.1Ω 5W resistor. The voltage is only around 30mV with 300mA flowing. Voltage at the negative terminal of the panel does go (slightly) negative with respect to 0V when there is a solar panel current flow.

This voltage is inverted and amplified by IC2b, which has a gain of –50. Therefore, IC2b's output will be around 1V per 200mA of current flow from the solar panel. This output is applied to the AN4 input of IC1 via a current-limiting 2.2kΩ resistor.

Note that the actual calibration of voltage and current is not overly important. Software within IC1 multiplies the voltage and current readings obtained at the AN3 and AN4 inputs to find where the maximum power point is for the solar panel. This calculation is not after any particular value, but just the maximum in a series of power calculations. It does this calculation periodically once every 20 seconds, and varies the on and off duty cycle of MOSFET Q1 to find the duty cycle that provides the maximum power from the solar panels.

Power for the remainder of the Solar-Powered Lighting Controller circuit is from the 12V SLA battery via a TL499A regulator, IC4. This is a low quiescent current type that can run as a linear step-down regulator and as a switch-mode step-up regulator.

We have used it as a 12V to 5V linear regulator, with the output voltage trimmed using trimpot VR1. Setting the output to 5V calibrates the analogue-to-digital conversion within IC1, ensuring correct charging voltages for the battery.

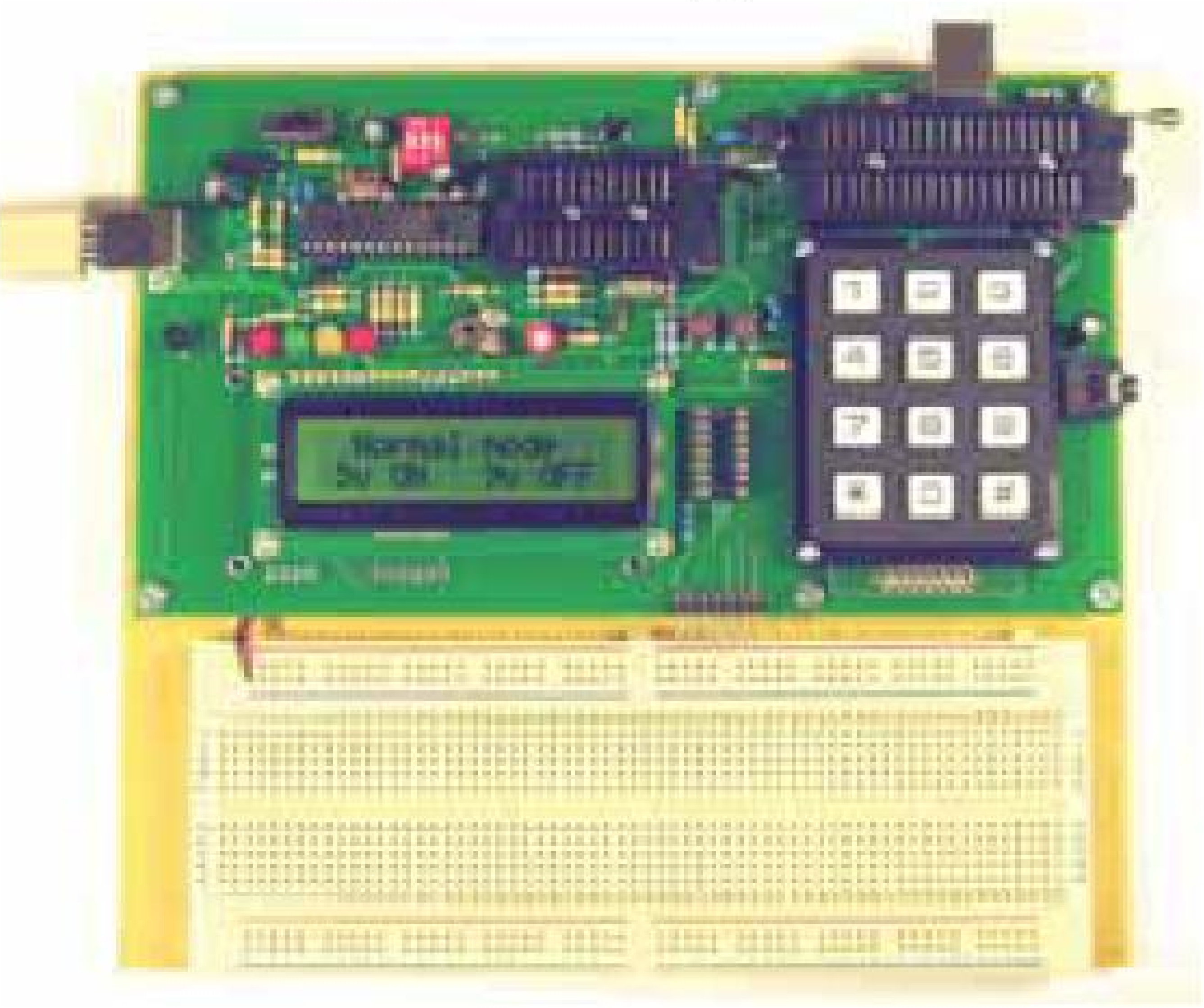
Protection against reverse polarity connection of both the 12V battery and solar panel are included. If the solar panel is connected with reverse polarity, IC2 is protected because Zener diode ZD2 will conduct in its forward direction, preventing more than 0.6V reverse voltage applied across its pin 4 and pin 8 supply rails. Diode D1 prevents reverse voltage being applied to the remainder of the circuit.

Should the battery be connected back to front, diode D2 will conduct via inductor L1 and the fuse, F1. The fuse will blow breaking the connection.

Next month

Next month, we'll cover full constructional details and even show how we made some LED lights to go with the project.

PIC Training Course



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This third stage of our PIC training course starts with simple experiments using 18F PICs. We use the PIC to flash LEDs and to write text to the LCD. Then we begin our study of PC programming by using Visual C# to create simple self contained PC programmes. When we have a basic understanding of PC programming we experiment with simple PC to PIC serial communication. We use the PC to control how the PIC lights the LEDs then send text messages both ways. We use Visual C# to experiment with using the PC to display sinewaves from simple mathematics. Then we expand our PC and PIC programmes gradually until a full digital storage oscilloscope is created. For all these experiments we use the programmer as our test bed. When we need the serial link to the PC we flip the red switches to put the control PIC into its USB to USART mode.

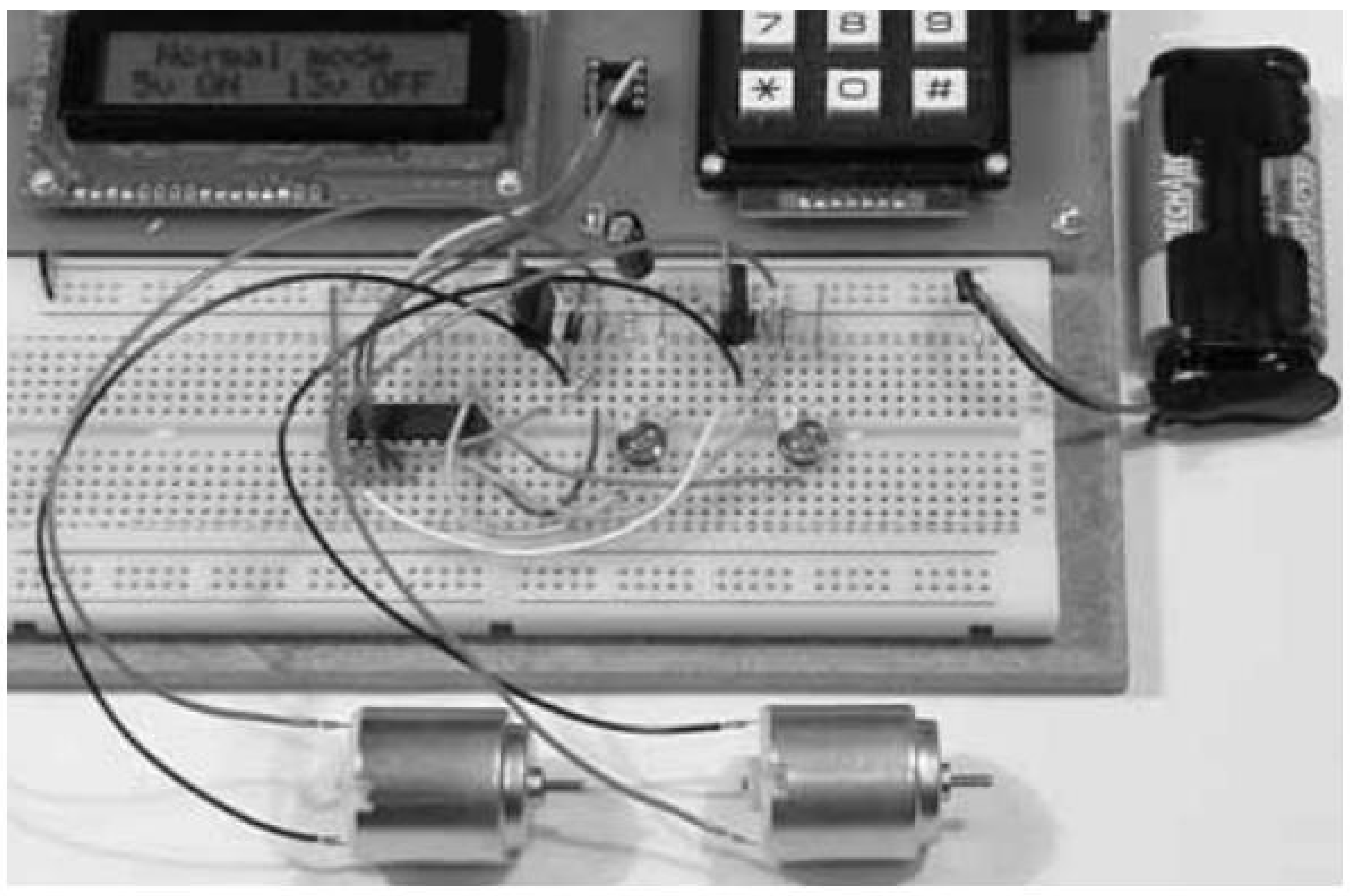
The second half of *Experimenting with Serial Communications* 4th Edition starts with an introduction to our Easy USB. Then we repeat some of the serial experiments but this time we use a PIC18F2450 with its own USB port which we connect directly to a USB port of your PC. We follow this with essential background study then work through a complete project to use a PIC to measure temperatures, send the raw data to the PC, and use the PC to calculate and display the temperature.

Easy USB is a perfect solution for simple and medium complexity project. For complex projects or where the timing is critical it is best to split the action between two or more PICs. In the last chapter of the book we complete the study by learning how to use the library routines to programme a PIC18F2450 as a USB to USART converter.

290 page book + PIC18F2450 test PIC + USB lead.. £31

Ordering Information

Our P931 programmer connects directly to a USB port on your PC and takes its power from the USB. All software referred to in this advertisement will operate within Windows XP, NT, 2000, Vista, 7 etc. Telephone for a chat to help make your choice then use Google checkout to place the order, or send cheque/PO, or request bank details for direct transfer. All prices include VAT if applicable.



White LED and Motors

Our PIC training system uses a very practical approach. Towards the end of the PIC C book circuits need to be built on the plugboard. The 5 volt supply which is already wired to the plugboard has a current limit setting which ensures that even the most severe wiring errors will not be a fire hazard and are very unlikely to damage PICs or other ICs.

We use a PIC16F1827 as a freezer thaw monitor, as a step up switching regulator to drive 3 ultra bright white LEDs, and to control the speed of a DC motor with maximum torque still available. A kit of parts can be purchased (£31) to build the circuits using the white LEDs and the two motors. See our web site for details.

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Jump Start

By Mike and Richard Tooley

Circuit design and build projects dedicated to newcomers, or those following courses taught in schools and colleges.

WELCOME to *Jump Start* – our new series of seasonal 'design and build' projects for newcomers. *Jump Start* is designed to provide you with a practical introduction to the design and realisation of a variety of simple, but useful, electronic circuits. The series will have a seasonal flavour, and is based on simple, easy-build projects that will appeal to newcomers to electronics, as well as those following formal courses taught in schools and colleges.

Each part uses the popular and powerful 'Circuit Wizard' software package as a design, simulation and printed circuit board layout tool. For a full introduction to Circuit Wizard, readers should look at our previous *Teach-In series*, which is now available in book form from Wimborne Publishing (see *Direct Book Service* page 76 in this issue).

Each of our Jump Start *circuits will include the following features:*

- ***Under the hood*** **–** will provide a little gentle theory to support the general principle/theory behind the circuit involved
- ***Design notes*** **–** will have a brief explanation of the circuit, how it works and reasons for the choice of components
- ***Circuit Wizard*** **–** will be used for circuit diagrams and other artwork. To maximise compatibility we have provided two different versions of the Circuit Wizard files; one for the education version and one for the standard version (as supplied by *EPE*). In addition, some parts will have additional files for download (for example, templates for laser cutting)
- ***Get real*** **–** will introduce you to some interesting and often quirky snippets of information that might just help you avoid some pitfalls
- ***Take it further*** **–** will provide you with suggestions for building the circuit and manufacturing a prototype. As well as basic construction information, we will provide you with ideas for realising your design and making it into a complete project
- ***Photo Gallery*** **–** showing how we developed and built each of the projects.

Moisture Detector

Our series starts this month with a simple moisture detector – ideal for use as a rain alarm, flood alert, or as a means of determining whether plants should be watered (or not!).

Under the hood

Our *Moisture Alarm* uses only three simple semiconductor devices and a home-made moisture sensor. Two of the semiconductors are bipolar junction transistors (BJT), while the third is a silicon-controlled rectifier (SCR). The two transistors (both *PNP* types – see Fig. 1) are needed to amplify the tiny current that our home-made rain sensor produces, and they are connected in a high-gain Darlington configuration (see Fig. 2). The output of the Darlington stage supplies current to trigger the SCR. This device acts as a latched switch (more about this later) which, when triggered, remains 'on', supplying current to an inexpensive electronic buzzer.

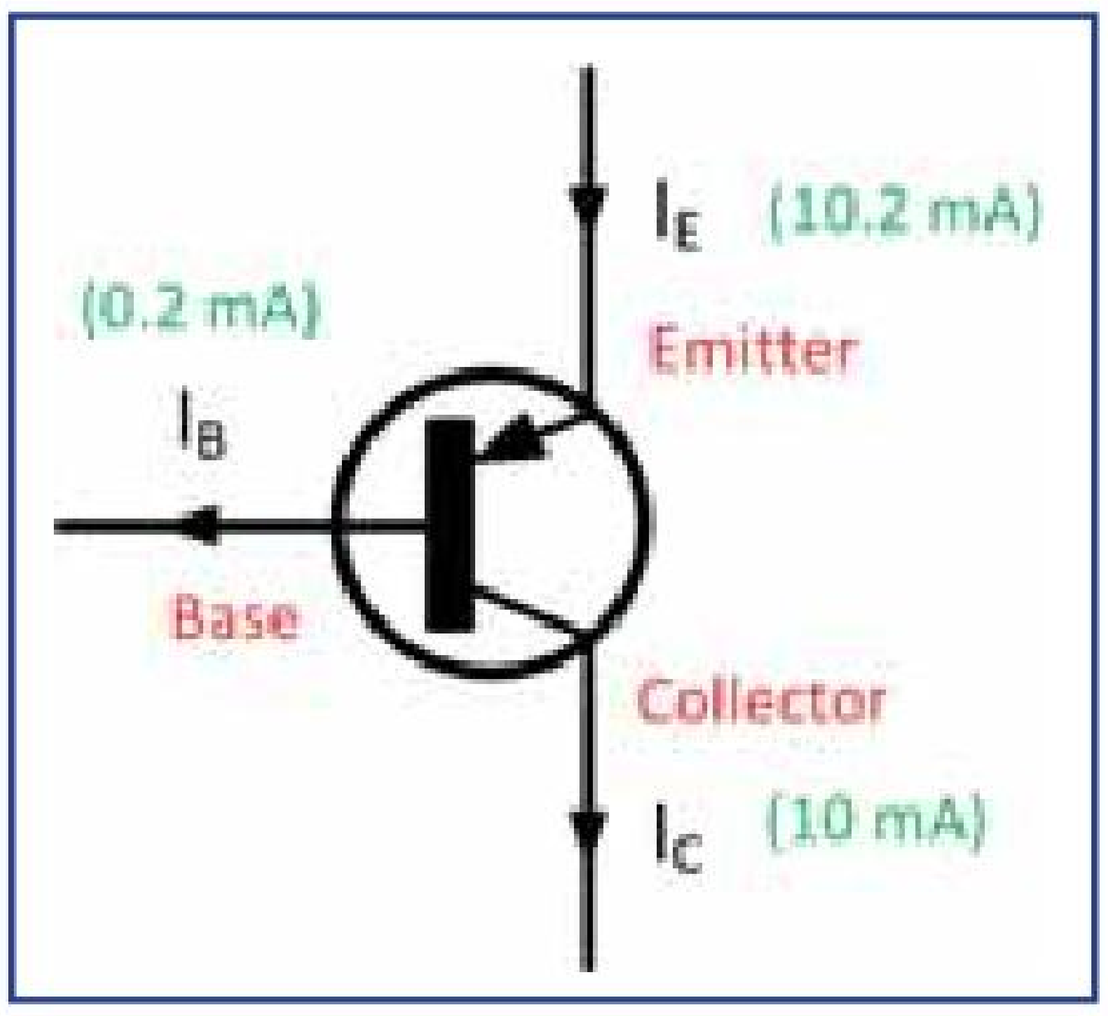


Fig.1. A *PNP* transistor showing typical current flow

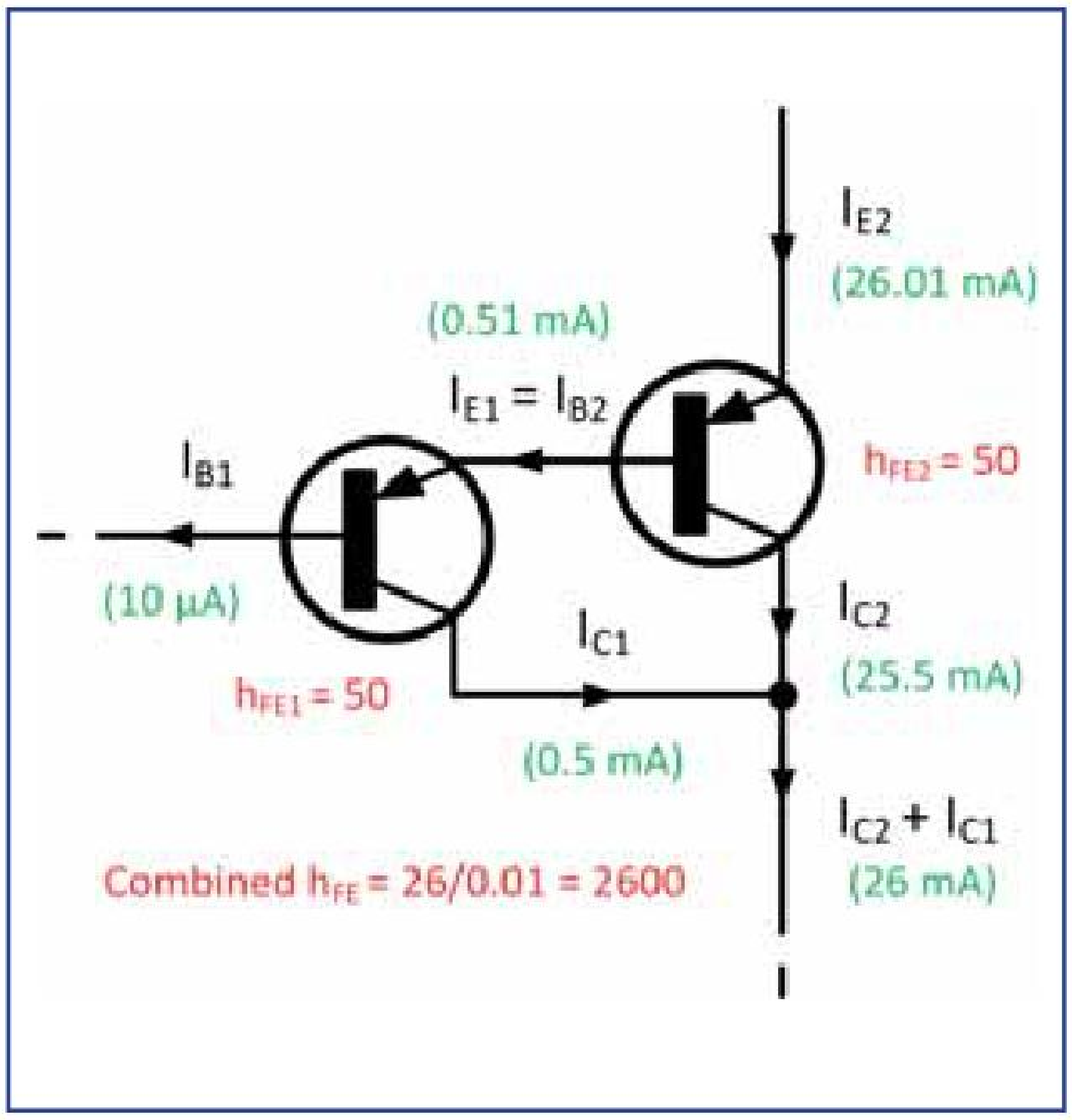
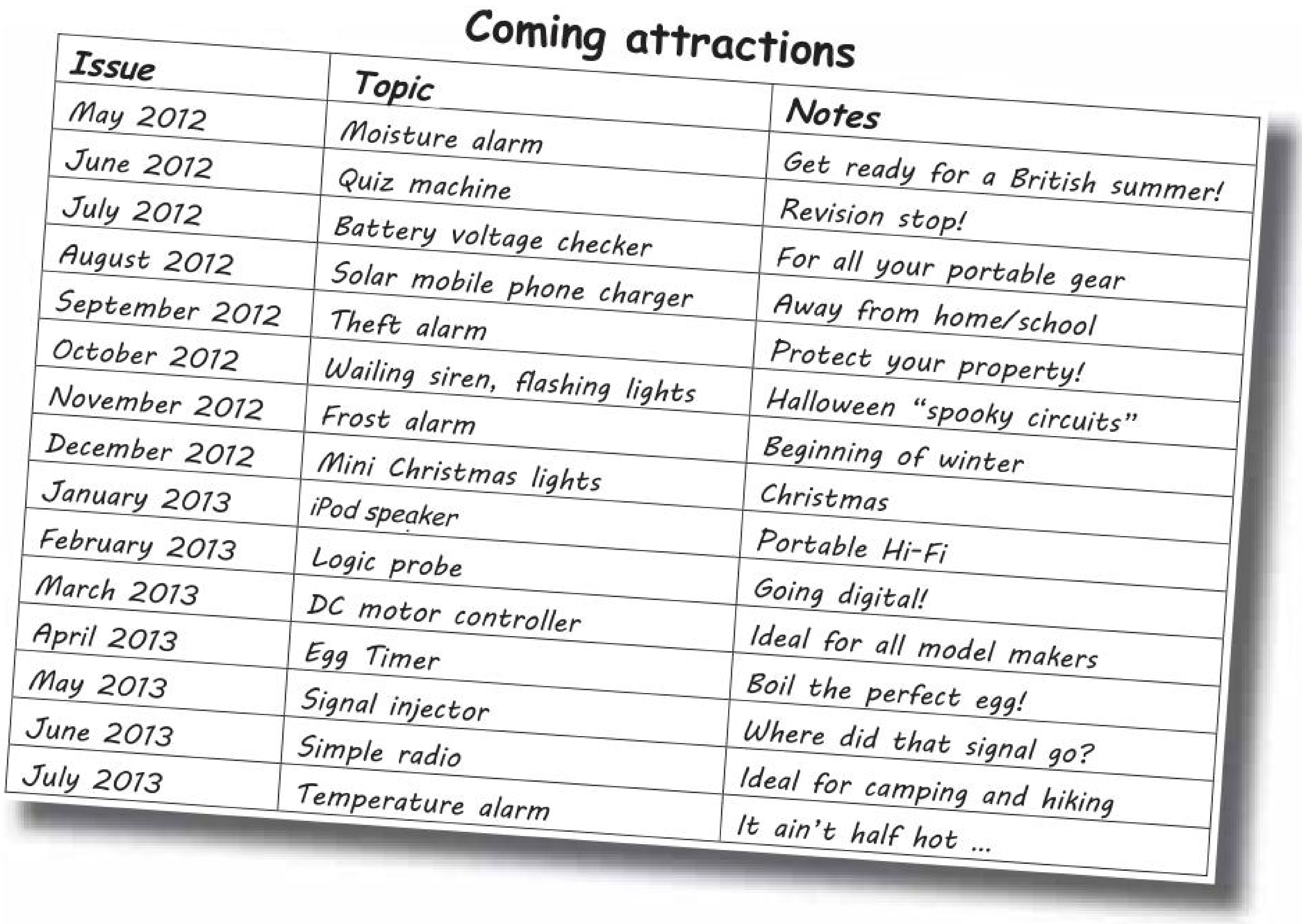


Fig.2. Two *PNP* transistors connected in a *PNP* Darlington configuration



Coming attractions

Issue	Topic	Notes
May 2012	Moisture alarm	Get ready for a British summer!
June 2012	Quiz machine	Revision stop!
July 2012	Battery voltage checker	For all your portable gear
August 2012	Solar mobile phone charger	Away from home/school
September 2012	Theft alarm	Protect your property!
October 2012	Wailing siren, flashing lights	Halloween "spooky circuits"
November 2012	Frost alarm	Beginning of winter
December 2012	Mini Christmas lights	Christmas
January 2013	iPod speaker	Portable Hi-Fi
February 2013	Logic probe	Going digital!
March 2013	DC motor controller	Ideal for all model makers
April 2013	Egg Timer	Boil the perfect egg!
May 2013	Signal injector	Where did that signal go?
June 2013	Simple radio	Ideal for camping and hiking
July 2013	Temperature alarm	It ain't half hot ...

The current flow in a *PNP* transistor is shown in Fig. 1. The equation that relates current flow in the collector (C), base (B), and emitter (E) of a transistor is:

$$I_E = I_B + I_C$$

where I_E is the emitter current, I_B is the base current, and I_C is the collector current (all expressed in the same units). When connected in common-emitter mode, the current gain, h_{FE}, provided by the transistor is given by the ratio of collector (output) to base (input) current. Hence:

$$h_{FE} = \frac{I_C}{I_B}$$

The current gain of the *PNP* transistor shown in Fig. 1 is thus:

$$h_{FE} = \frac{I_C}{I_B} = \frac{10}{0.2} = 50$$

When used as a current amplifier, with the input applied to the base and the output taken from the collector (we call this 'common-emitter mode'), the output current can be determined by rearranging the earlier h_{FE} equation, so that:

$$I_C = h_{FE} \times I_B$$

So, in the case of a transistor with an h_{FE} of 50, a base current of 0.2mA would result in a collector current of 10mA, and if the base current were to increase to 0.4mA the output current would increase to 20mA, and so on.

Darlington pair

The current gain of a single *PNP* transistor usually ranges between about 50 and 200. In order to achieve a higher value of gain we need to use more than one stage of amplification. Connecting two transistors in a Darlington configuration provides an extremely high current gain (approximately equal to the product of the individual current gains of the two transistors).

So, in Fig.2, if each transistor has a current gain of 50 (which is actually well below the minimum current gain for the BC557 transistor that we've used in the moisture detector), then the combined current gain will be 2600, and a current of only 10μA applied to the base of the first transistor will result in a collector current of 26mA flowing in the second transistor (see Fig. 2). This should be more than adequate for use in our moisture sensor!

Thyristors

Silicon-controlled rectifiers (or 'thyristors') are semiconductor devices with three terminals that can switch very rapidly from a non-conducting to a conducting state. In the 'off' state, the SCR passes negligible current, while in the 'on' state the device exhibits very low resistance and, depending on its rating, is capable of passing appreciable current.

Once switched into the conducting state, by applying current to the gate terminal, the SCR will remain conducting and will become 'latched' into the 'on' state (see Fig.3). The conducting state will continue until the 'forward current' is removed from the device.

In simple, direct current applications, this necessitates the interruption (or discon-nection) of the supply, after which the SCR will effectively become reset into its non-conducting state. The C106D SCR that we will be using in the moisture detector requires a minimum gate trigger current of 0.2mA, and a maximum gate trigger voltage of 1.5V.

The sensor used in our moisture detector is simply a series of conductive copper strips etched on a small piece of printed circuit board

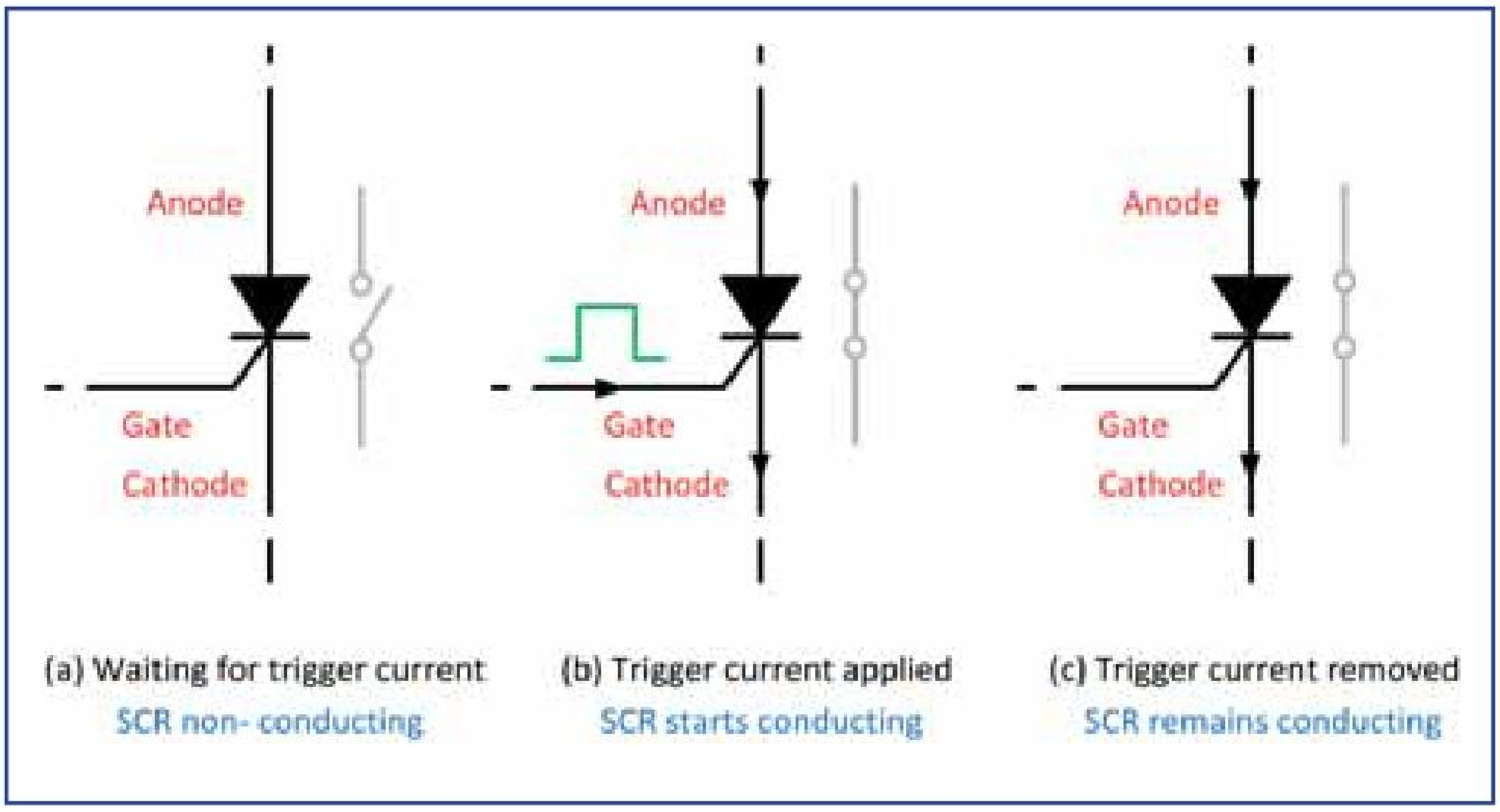


Fig.3. An SCR in its conducting and non-conducting states

(PCB). In a dry environment the resistance between the two strips will be very high, but in the presence of moisture (eg, condensation, raindrops or mist.) the resistance will fall significantly. A typical 'dry' resistance will be many tens or hundreds of MΩ, while the resistance in the presence of moisture will typically fall to less than 5MΩ.

Get real!

In liquids, electrical conduction is by means of the motion of ions, which convey an electric charge. Because not many ions are present in pure water, it is not a good conductor of electricity. The conductivity of water falls in the presence of inorganic dissolved solids (eg, salt). It also falls as the temperature rises: the warmer the water, the higher the conductivity. Typical conductivities for different types of water are shown in Table 1.

Design notes

The complete circuit of the prototype moisture detector (produced using Circuit Wizard) is shown in Fig.4. Transistors Q1 and Q2 form the Darlington pair, with current supplied to Q1 via the moisture sensor connected to terminal block CN1. The sensitivity of the circuit is made variable by means of the preset potentiometer (wired as a variable resistor), VR1. The collector current from Q2 is fed to the gate of the SCR, D1, via a potential divider formed by resistors R2 and R3. Resistor R2 limits the current that is supplied to the gate of D1 when it is triggered (a current of only 2mA is sufficient to trigger the SCR).

When conducting, the anode current of the SCR flows through warning buzzer BZ1. LED D2 and resistor R4 provide a visible indication (useful in applications where an audible indication is not required). The SCR is reset (back to its pre-latched state) by interrupting the anode current flow. Note also that we've added a second 'variable resistor' (VR2) in parallel with the moisture sensor input so that we can test the circuit (see later).

Table1: Typical conductivities of water

Type of water	*Typical conductivity*
Highly pure water	0.06μS/cm
Pure water	5 to 10μS/cm
Drinking water	50μS/cm
Inland fresh water	150 to 500μS/cm
River water	500μS/cm
Sea water	50mS/cm

Circuit Wizard

SOFTWARE tools are used throughout the electronic design process. They help us not only to design and develop our circuits, but also to test them out before any soldering iron gets hot.

The software we will be using throughout the *Jump Start* series is 'Circuit Wizard'. It's a fantastic piece of software that the authors have used for many years for teaching in schools/colleges. It lets you enter and simulate your circuits in real time, and then take the circuit information and create a printed circuit board (PCB) design that you can make for real.

In our recent *Teach-In 2011* series, we used Circuit Wizard as a tool that uses animation and visualisation techniques to see how circuits really work. As we progressed through the series we saw how Circuit Wizard could also be used as an excellent electronics design tool, following the process all the way from entering components to producing the PCB designs for a number of simple projects.

The *Teach-In 2011* series is perfect for newcomers to explore the basic theory of electronics, as well as those 'brushing up' on their understanding. If you didn't follow the series, don't worry, we'll be giving you some basic advice along the way, although we do recommend reading the series to get you up to speed.

Back orders covering the *Teach-In* series of *EPE* are available through the *EPE* website: **www.epemag.wimborne.co.uk**. Alternatively, the full *Teach-In* series may be purchased as a special compendium edition – see page 76 of this issue for further details.

You can find out more about Circuit Wizard at the New Wave Concepts website: **www.new-wave-concepts.com**. Copies of the software may be purchased at special rates from *EPE* – see opposite page. We'll also be making available all of the circuit files together with lots of other useful tools/information on the author's website: **www.tooley.co.uk/epe**.

We're also keen to hear your views and ideas for the *Jump Start* series as well as any questions that you may have. You can get in touch directly with the authors at: **jumpstart@tooley.co.uk**. We would also love to see some of the circuits that you've produced following the series – send your files/photos to us and you could even get published in a future edition!

Simulating the circuit

Right, let's see how our first *Jump Start* project simulates in Circuit Wizard before we progress to a printed circuit design that we will actually build. Carefully enter the circuit shown in Fig.4, making sure that you select the correct device for each component that you add to the page from the component gallery (double-click the

A note regarding Circuit Wizard versions:

Circuit Wizard is available in several variants; Standard, Professional and Education (available to educational institutions only). Please note that the component library, virtual instruments and features available do differ for each variant, as do the licensing limitations. Therefore, you should check which is relevant to you before purchase. During the Jump Start *series we aim to use circuits/features of the software that are compatible with the latest versions of all variants of the software. However, we cannot guarantee that all items will be operational with every variant/version.*

component or right-click on Properties and select the appropriate variant from the 'model' drop-down list).

The software will happily simulate a circuit using standard/generic component parameters if a *specific* device type is not selected. However, it's important to get the device specifications right, as they can affect the operation of the circuit. This information is also used by Circuit Wizard to get the correct pin connections when the software converts the design to a PCB.

Obviously, there's no 'moisture sensor' component in the software. Therefore, we've included an additional large value variable (potentiometer) resistor (VR2) to mimic the resistance of the sensor and test the circuit operation. Before running the simulation, set VR1 to about 50% and VR2 to 100% (5MΩ). Run the simulation and observe the operation as you lower the resistance of VR2 to simulate an increasing moisture level. Preset VR1 can be varied to control the level at which the alarm is activated. Note that you will need to stop and restart the simulation to 'reset' the thyristor once triggered.

Next, try experimenting with different circuit views. The 'Current Flow' view is really useful to help us see exactly what's going on in the circuit. You should notice that as the resistance of VR2 is reduced (as it would with increased moisture), the current flowing into the transistor pair is increased very slightly. This is then amplified by the transistors and used to control the gate of the thyristor. When 'on', the thyristor allows current to flow down from the supply through LED D2 and buzzer (BZ1) to ground (0V), and hence operating them.

Now we're satisfied that the circuit operates correctly, we're ready to work it into a fully operational product that we can make for real. We've given you two examples of this; a handheld plant pot moisture sensor, to help identify if your favourite plant needs a drink, and a rain alarm, so that you know when to rush out and get your washing in.

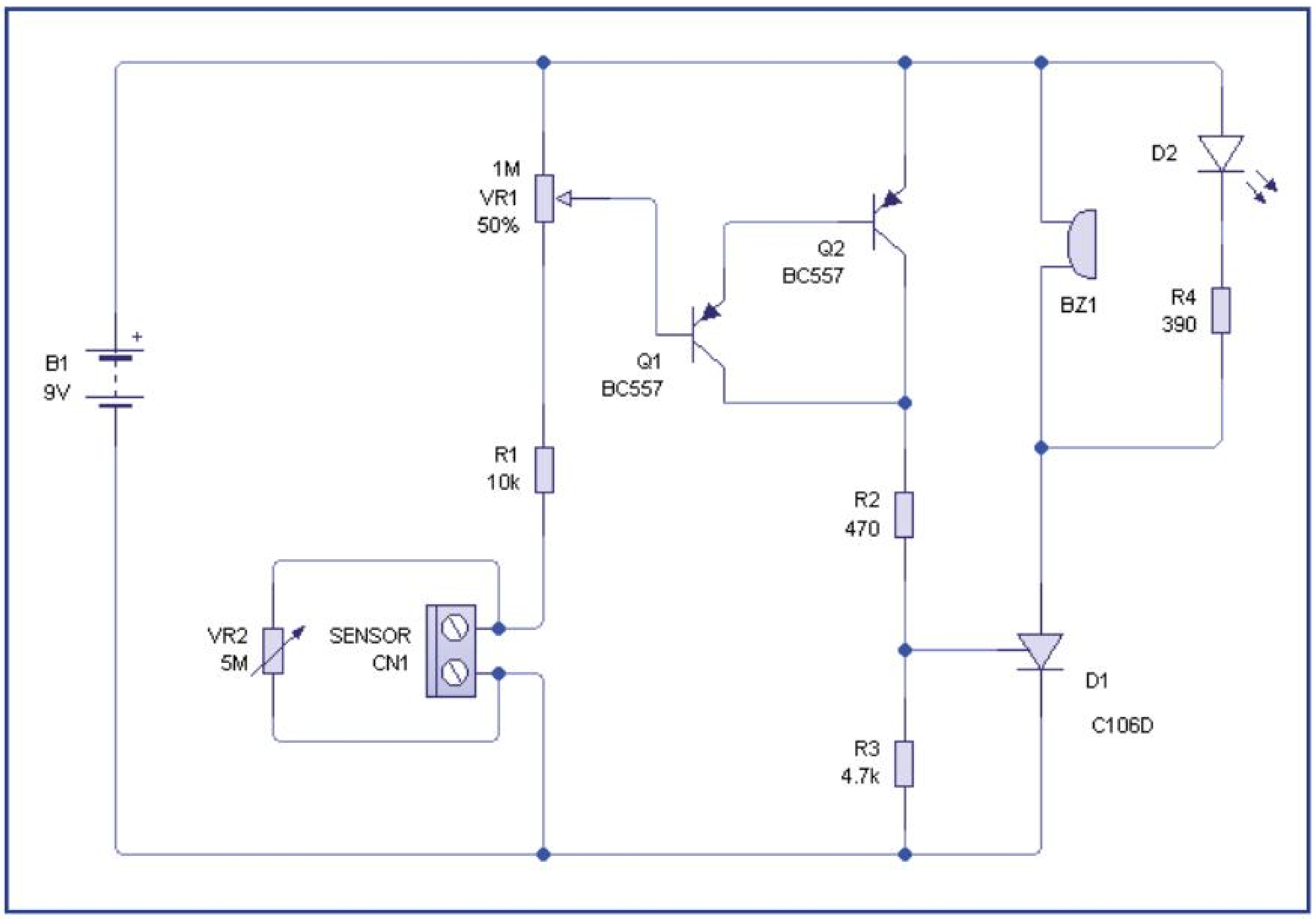
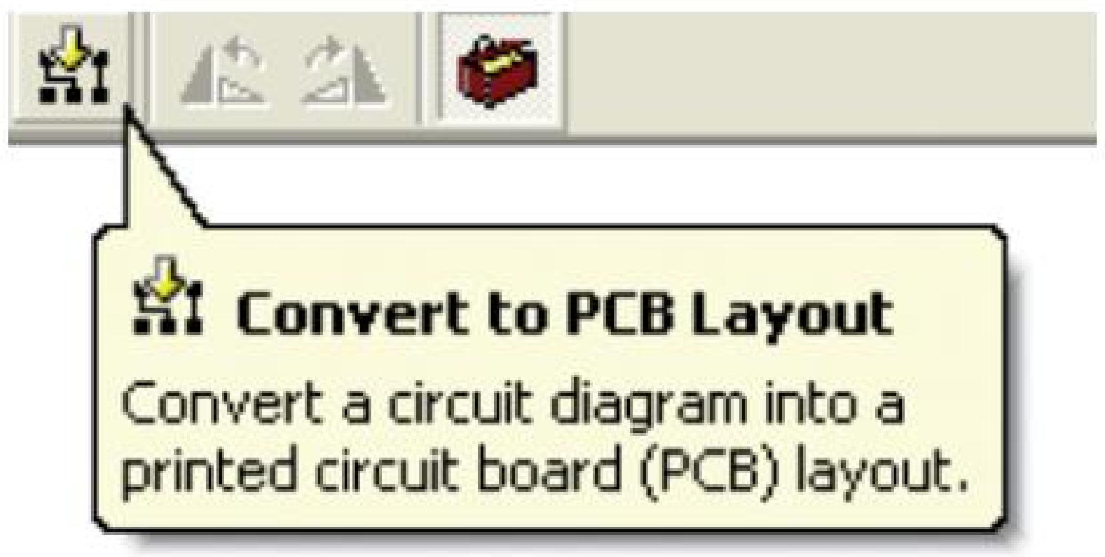


Fig.4. Moisture detector circuit ready for simulation in Circuit Wizard

As with all of the *Jump Start* circuits, we'll be giving you some ideas on how to realise them into a working device. You are free to use our own designs (downloadable from the author's *Jump Start* website at: **www.tooley.co.uk/epe**). However, to really get the most out of the series you should try out your own skills and create your own PCB designs (see Fig.5). By taking time to play with the circuits, tweaking and adapting them to you your needs and creating your own PCB layouts you'll soon be making your very own electronic boards, just like the pros!



Convert to PCB Layout

Convert a circuit diagram into a printed circuit board (PCB) layout.

Fig.5. The Circuit Wizard 'Convert to PCB' tool

Get real!

It's now time to put what we've learned into practice by looking at two practical applications for the circuit that we've just developed. The first of these takes the form of a handheld plant pot moisture sensor, while the second is a rain alarm that provides an audible warning when rainfall is detected.

CIRCUIT WIZARD

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

Circuit Wizard is a revolutionary new software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.

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- *Circuit diagram design with component library (500 components Standard, 1500 components Professional)*
- *Virtual instruments (4 Standard, 7 Professional)*
- *On-screen animation*
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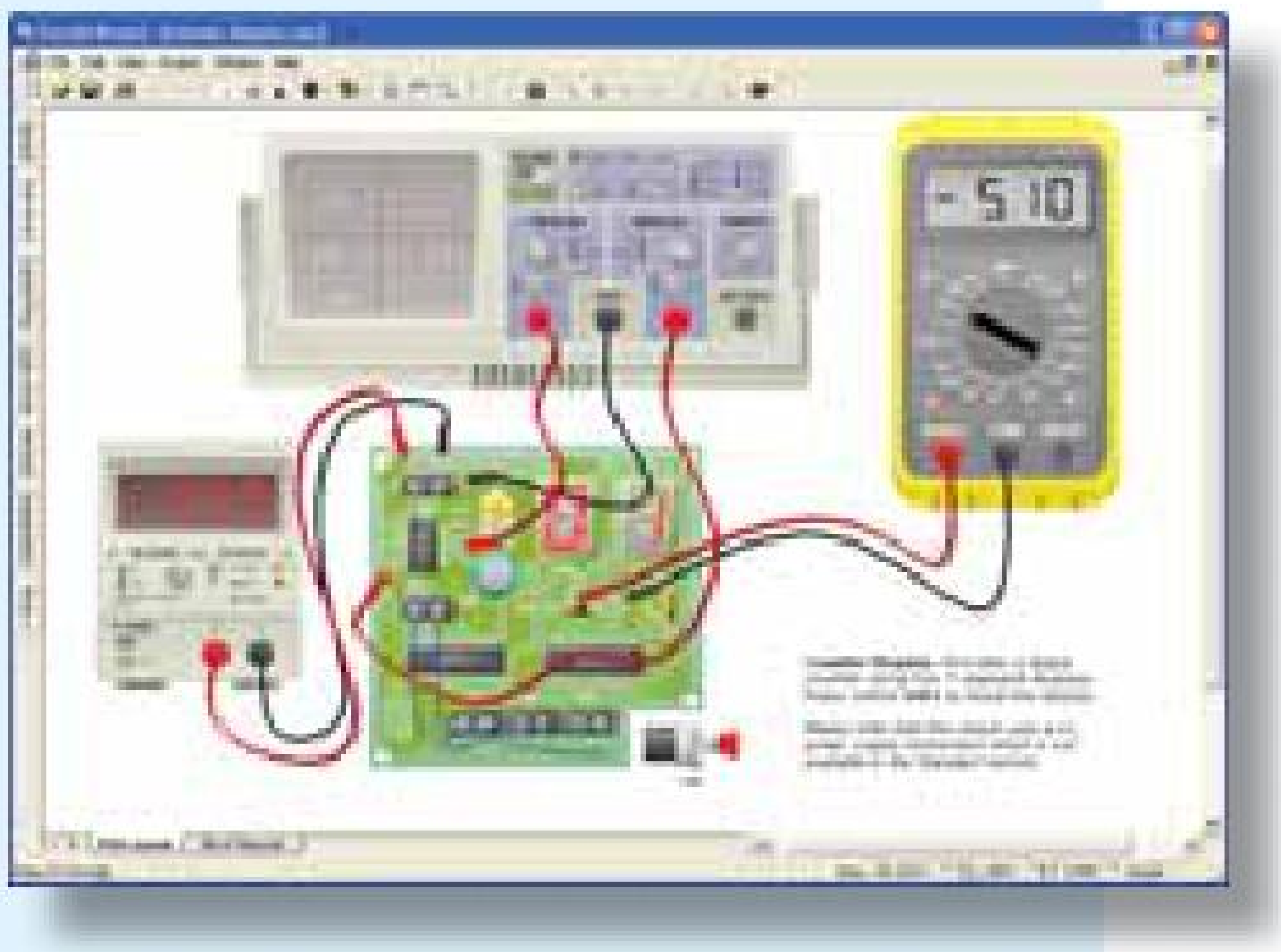
- *Multiple document support*



This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT Professional **£91.90** inc. VAT

Plant Pot Moisture Sensor

FOR the plant pot version of our moisture sensor, shown in Fig.6, we've taken out the buzzer and added a push-to-make switch (SW1) to act as a 'test button'. Once inserted into the soil, if moist, the green LED D1 will light and remain 'on' when SW1 is pressed.

We want SW1 to be a PCB-mounted tactile button. By default, Circuit Wizard will place an off-board connector for the button. To tell the software to use the circuit-mounted variety, you need to tick 'allow me to customise the PCB conversion' and then, when given a list of components found in your circuit, double-click 'Push to Make Switch' and select 'Push Switch (6mm × 6mm)' – see Fig.8.

We are going to model the actual circuit board as a handheld probe. Therefore, we are going to need to be quite specific about the position of the components. For this reason, when converting we de-selected 'Automatically place components on the board' during the PCB conversion wizard so that we are just given a 'rats nest' of components and nets so that we can place the components and route the tracks later – see Fig7 and Fig.9.

In this case, the battery connector was placed at the rear of the board with

You will need...

1 PC board/sensor, code 846, available from the *EPE PCB Service*, size 100mm × 60mm
1 mini 'tactile' pushbutton switch, PC-mounting, size 6mm × 6mm (SW1)
1 9V battery, with clip and leads (B1)
2 2-way PC-mounting screw terminal blocks (B1, CN1 – optional)

Semiconductors
2 BC557 *PNP* transistors (Q1, Q2)
1 C106D thyristor (D1)
1 5mm green LED (D2)

Resistors
1 10kΩ (R1) 1 470Ω (R2)
1 4.7kΩ (R3) 1 390Ω (R4)
1 1MΩ preset potentiometer, horizontal mounting

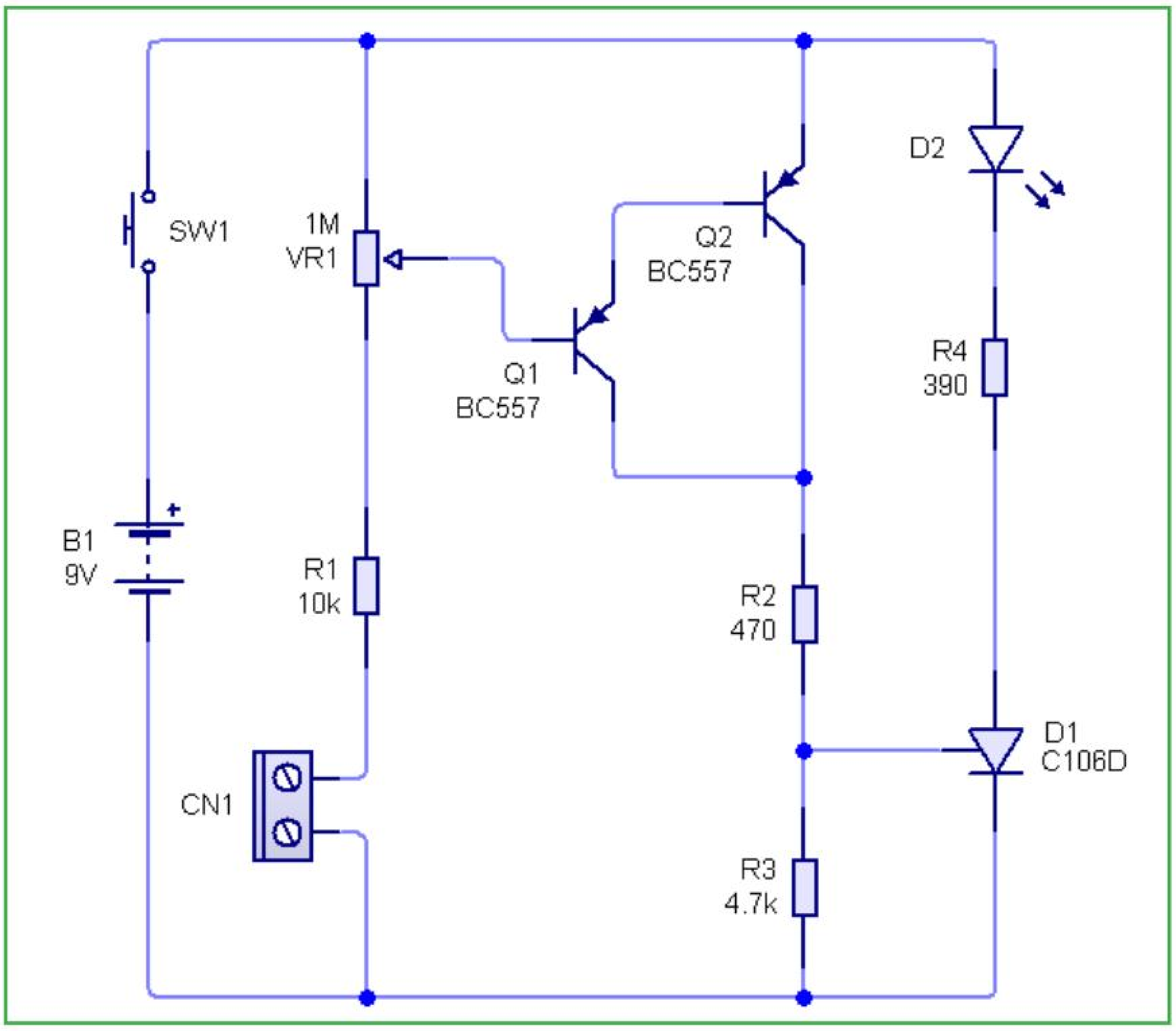
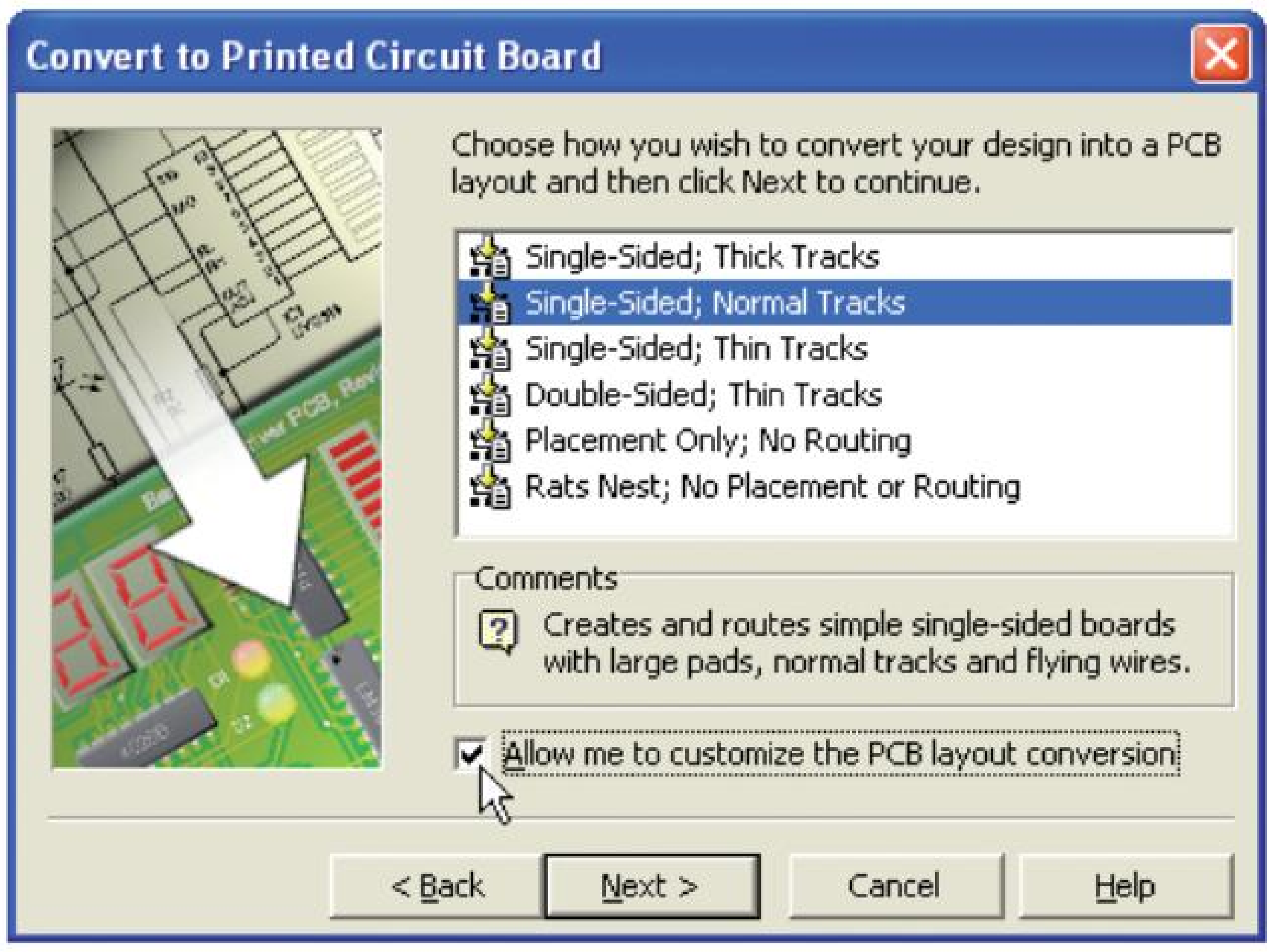


Fig.6. The plant pot moisture sensor circuit.


Convert to Printed Circuit Board

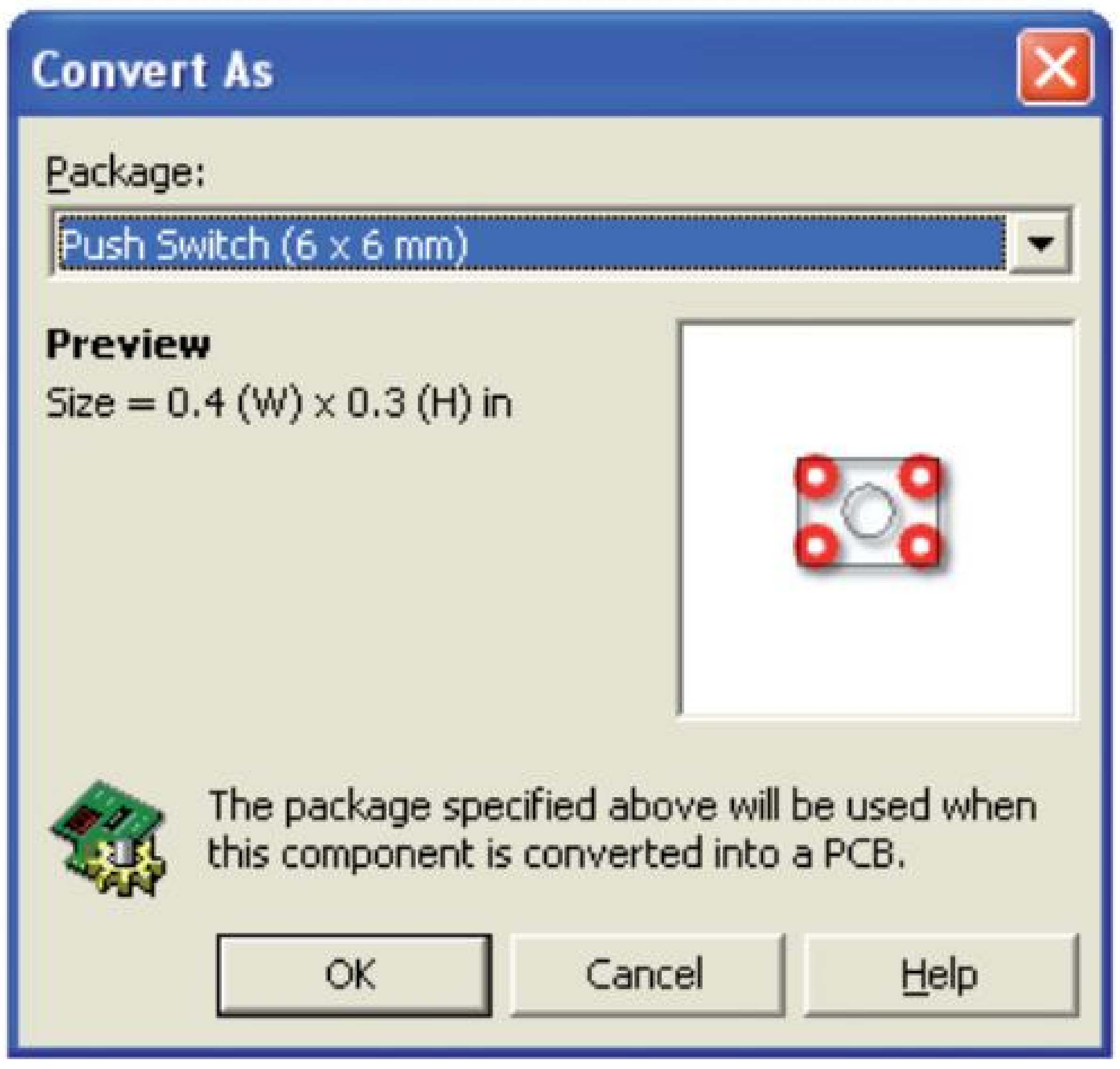
Choose how you wish to convert your design into a PCB layout and then click Next to continue.

- Single-Sided; Thick Tracks
- Single-Sided; Normal Tracks
- Single-Sided; Thin Tracks
- Double-Sided; Thin Tracks
- Placement Only; No Routing
- Rats Nest; No Placement or Routing

Comments
Creates and routes simple single-sided boards with large pads, normal tracks and flying wires.

☑ Allow me to customize the PCB layout conversion

Fig.7. The 'Convert to Printed Circuit Board' wizard has an option that allows users to customise a PCB layout

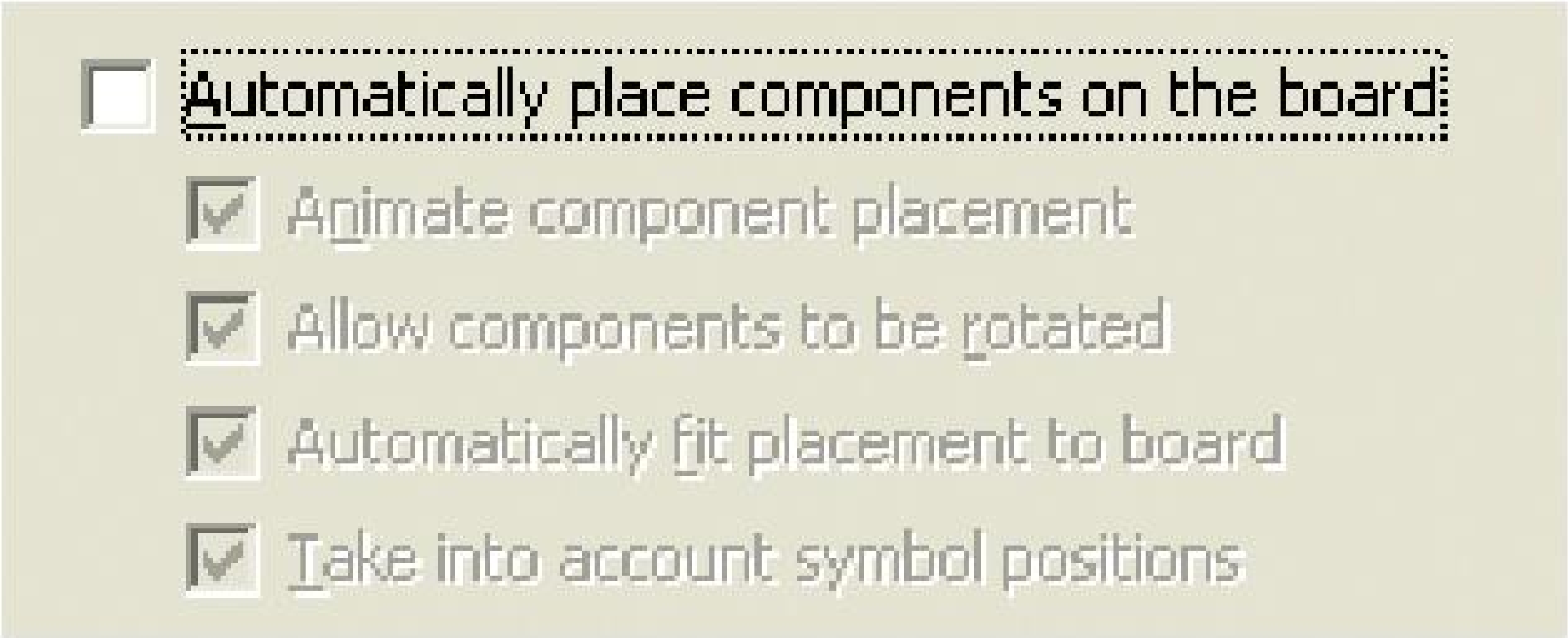

Convert As

Package: Push Switch (6 x 6 mm)

Preview
Size = 0.4 (W) x 0.3 (H) in

The package specified above will be used when this component is converted into a PCB.

Fig.8. Customising SW1 into a miniature push-to-make switch



☐ Automatically place components on the board

☑ Animate component placement

☑ Allow components to be rotated

☑ Automatically fit placement to board

☑ Take into account symbol positions

Fig.9. De-selecting Circuit Wizard's automatic routing options

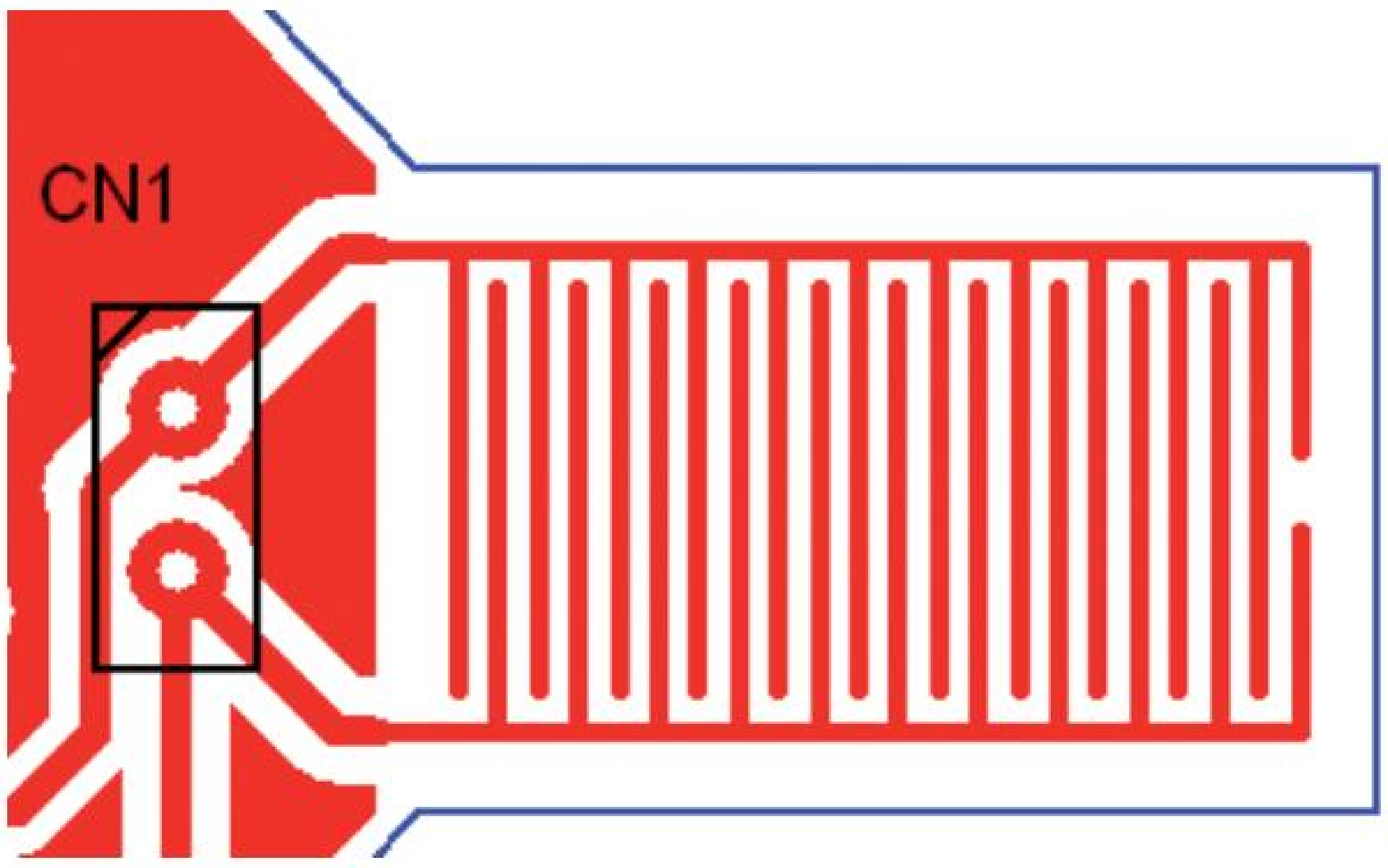


Fig.10. Plant pot moisture sensor design

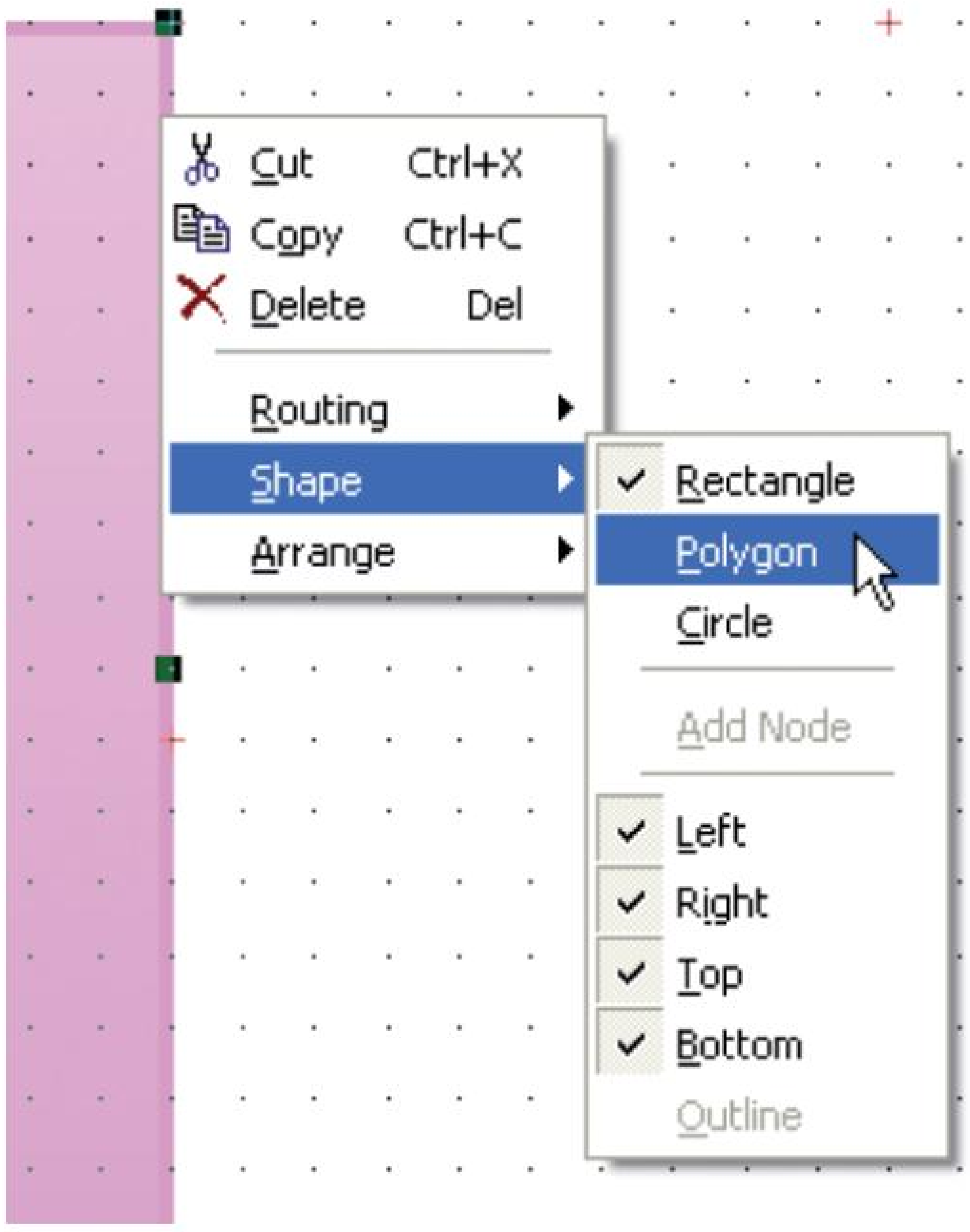
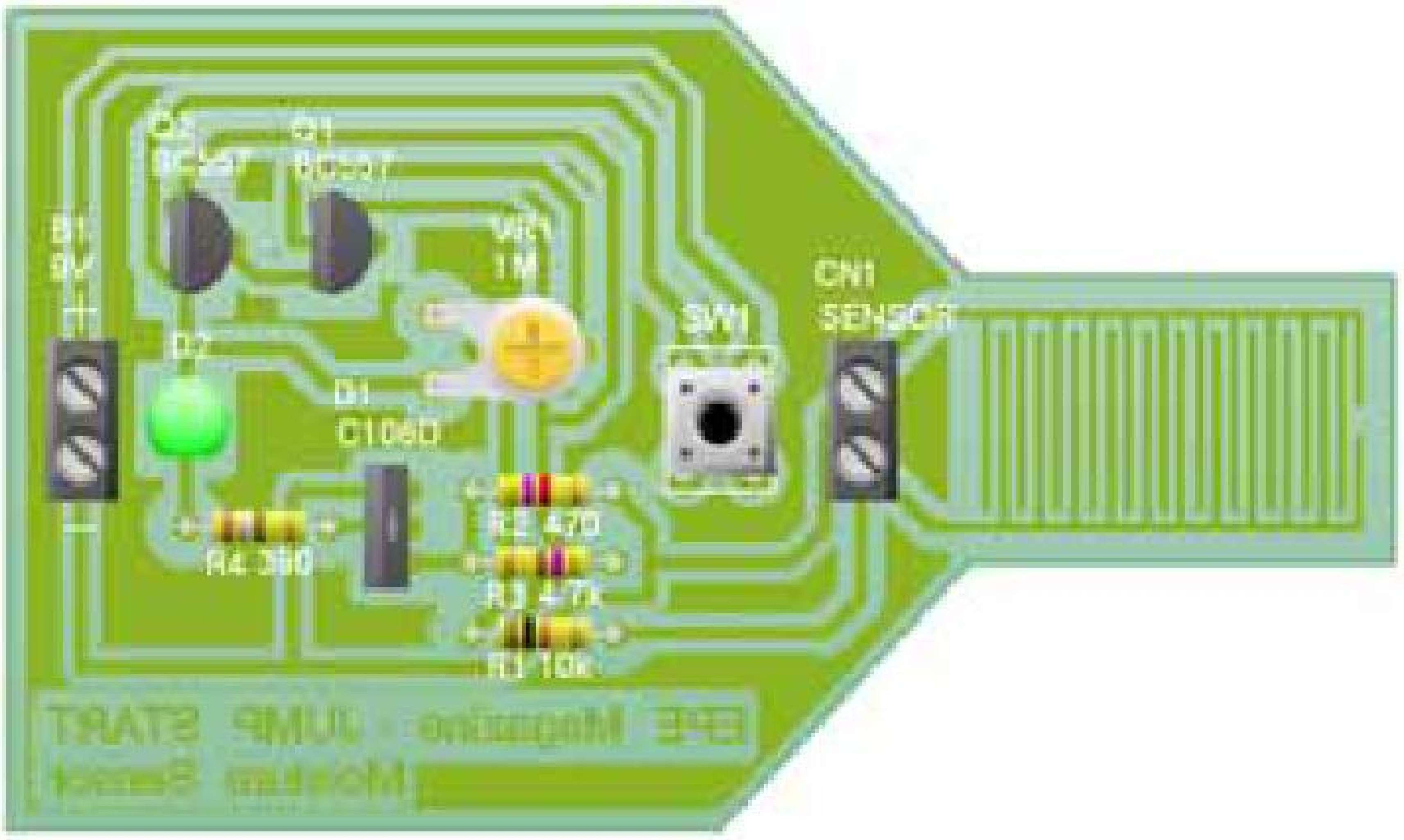

Cut Ctrl+X
Copy Ctrl+C
Delete Del
Routing
Shape
Arrange
Rectangle
Polygon
Circle
Add Node
Left
Right
Top
Bottom
Outline

Fig.11. Selecting the Polygon option from Circuit Wizard's Shape menu


Q2
BC557
Q1
BC557
B1
9V
VR1
1M
D2
D1
C106D
SW1
CN1
SENSOR
R4 390
R2 470
R3 4.7k
R1 10k

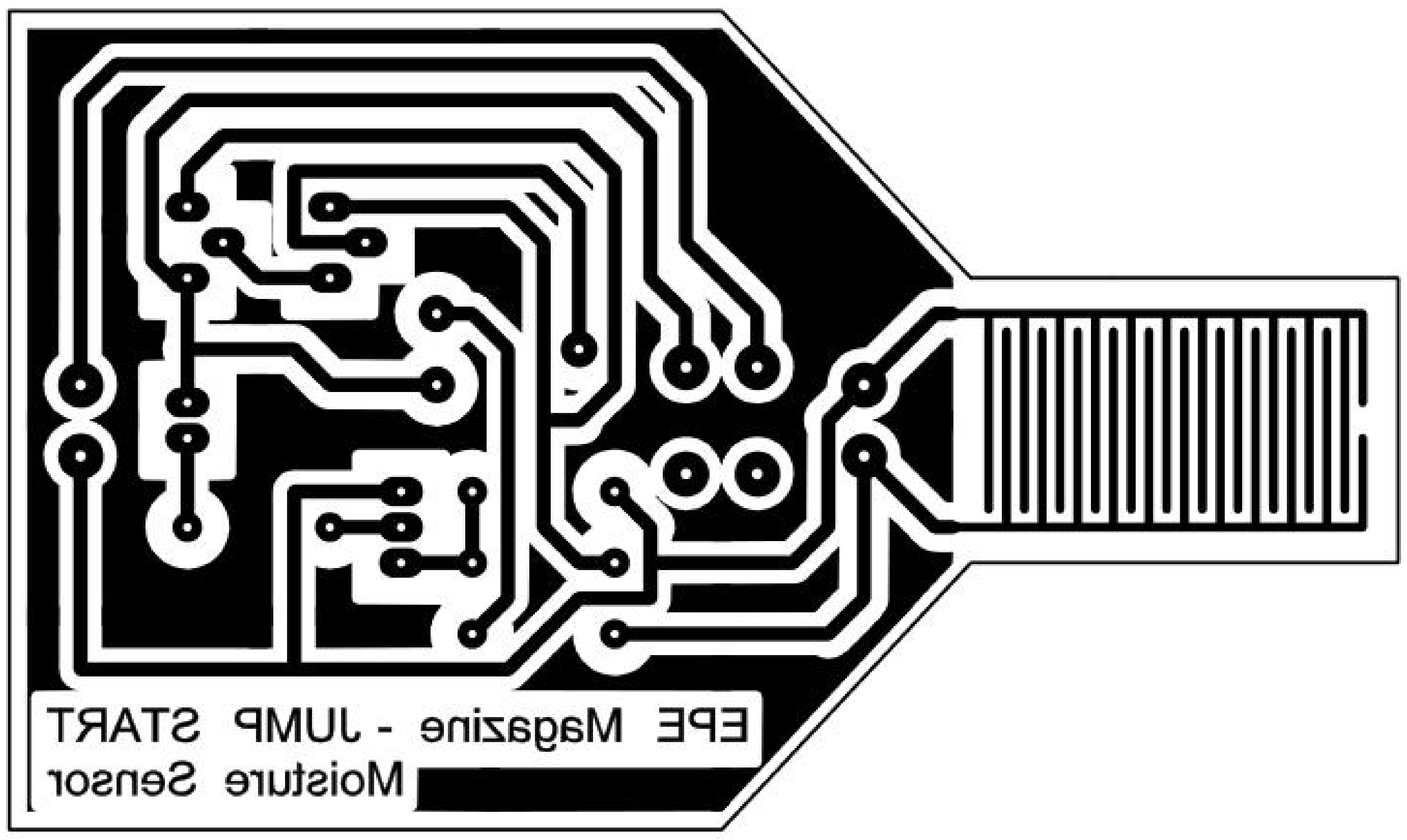

EPE Magazine - JUMP START
Moisture Sensor

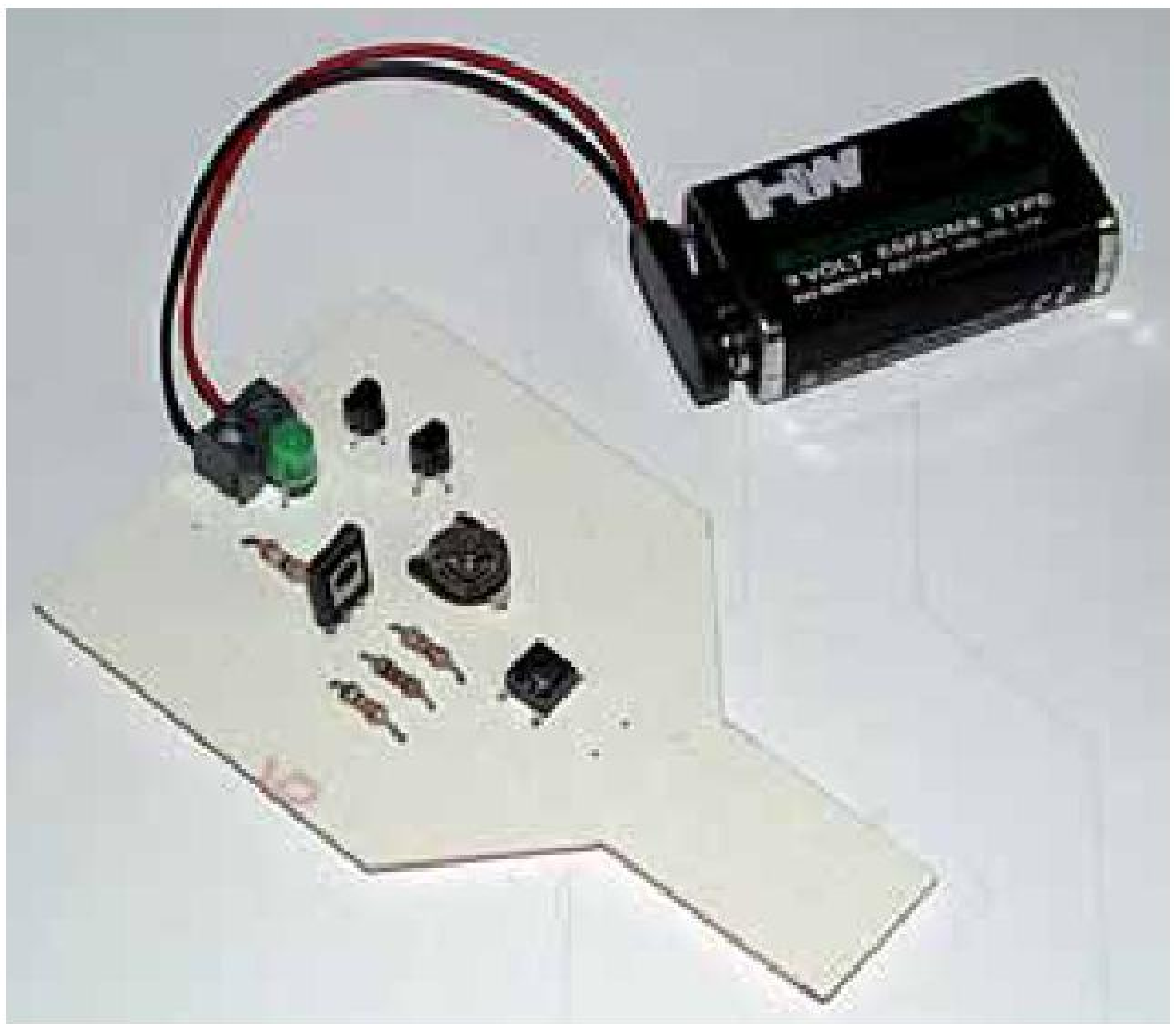
Fig.12. Finished component and corresponding PCB layouts produced by Circuit Wizard for the Plant Pot Moisture Sensor

the LED centred and the pushbutton in the front-centre of the board, where it can be easily pressed by the user. Tracks may be added either manually or by using the automatic routing features. (For more description of automatic routing and manual track drawing refer to our earlier *Teach-In 2011* series, which covers this in some detail.)

Sensor

We showed the connections for our moisture sensor as a two-way off-board connector (CN1) on our circuit diagram (Fig.6). In fact, we are going to draw the sensor directly on to the PCB (and not actually put in the connector). The sensor itself is simply many lines of interlocking copper track. To improve sensitivity we reduced the track and gap width – see Fig.10.

To achieve the 'soil probe' shape of the circuit board you need to convert the rectangular PCB shape into a polygon. To do this, right-click the circuit board and select 'Shape – Polygon' (see Fig.11). After this has been set, you should notice that the cursor appears as a small square when over the board outline. You can add a 'node' at any point on the board edge by clicking while holding the Ctrl key. In this way, you can add as many nodes/sides as you need to form a more complex shape.



Completed 'practical' Plant Pot Moisture Sensor

Rain Alarm

NOW FOR the Rain Alarm. This variation of the circuit (see Fig.13) has an audible alarm in the form of a buzzer mounted off-board. When drawing the circuit, simply add a two-pin connector (not the buzzer component, as the buzzer will be mounted 'off-board'). The sensor will actually be a separate PCB mounted off-board too.

The main circuit PCB and rain sensor PCBs were made to the same dimensions, with four fixing holes allowing them to be 'stacked' using a spacer and two machine head screws. In this way, the rain sensor is effectively mounted upside down, with the copper layer exposed to the falling rain.

Take it further

There are many further applications for our basic moisture sensor, quite apart from the two that we've described here. They include flood and burst pipe alarms and condensation sensors. Different sensor arrangements can be used to sense moisture over larger areas, and several may be connected in parallel to provide greater coverage.

There's also plenty of scope for modifying and improving the plant pot moisture sensor and the rain alarm. For example, the plant pot sensor could be made to provide an analogue indication of the amount of moisture present in the soil, by removing the thyristor and replacing resistor R2 with a moving coil meter having a full-scale deflection of 1mA, or so.

EPE Jump Start

You will need...

- 1* PCB main, code 847, size 64mm × 64mm
- 1* PCB sensor, code 848, size 64mm × 64mm
- 3 2-way PCB-mounting screw terminal blocks (CN1, CN2, B1)
- 1 9V battery, with clips and leads
- 1 6V to 9V mini buzzer

Semiconductors

- 2 BC557 *PNP* transistors (Q1, Q2)
- 1 C106D thyristor (D1)

Resistors

- 1 10kΩ (R1) 1 470Ω (R2)
- 1 4.7kΩ (R3)
- 1 1MΩ preset potentiometer, PC-mounting, horizontal
- * available as a pair from the *EPE PCB Service*

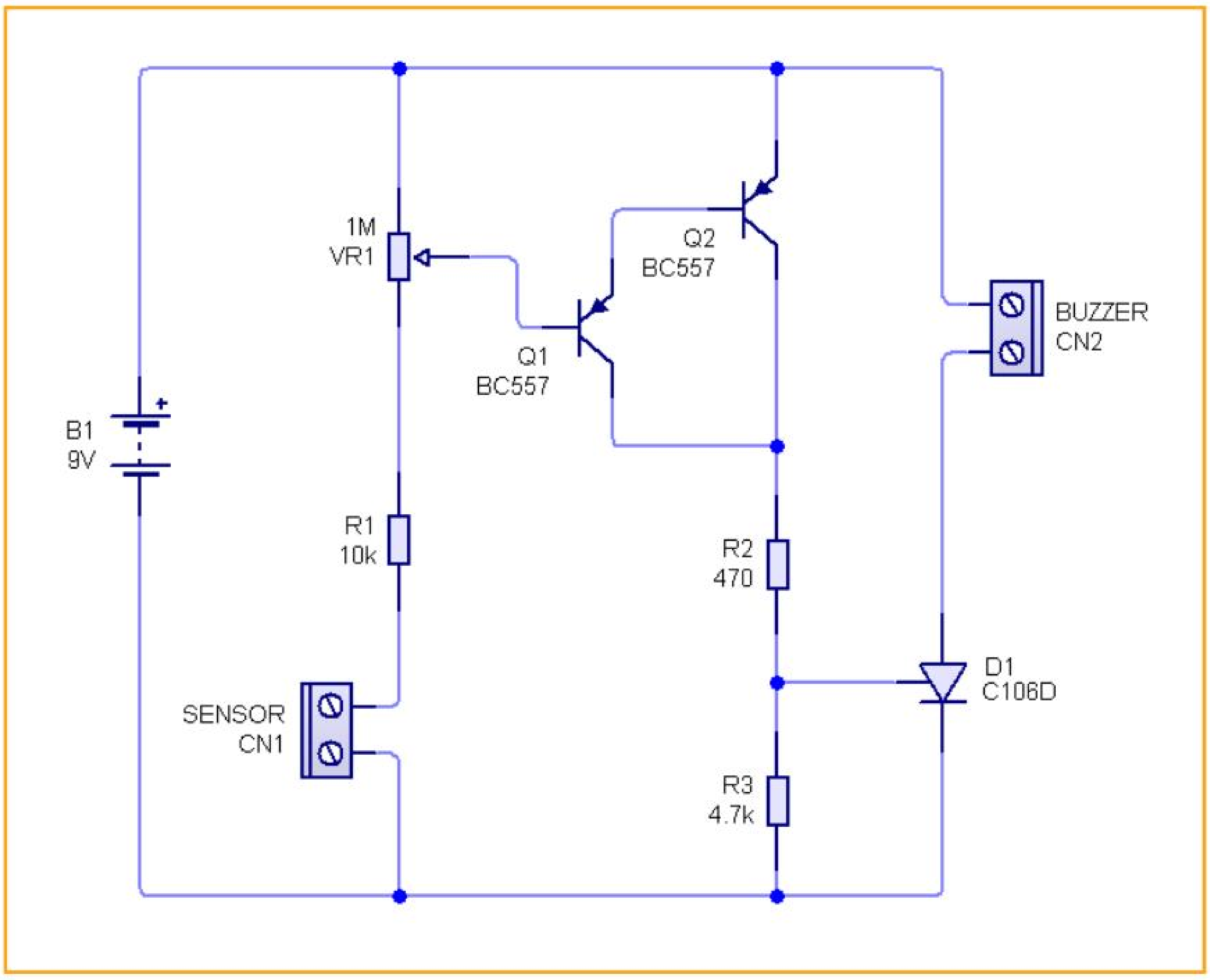

1M
VR1
Q2
BC557
Q1
BC557
B1
9V
+
BUZZER
CN2
R1
10k
R2
470
D1
C106D
SENSOR
CN1
R3
4.7k

Fig.13 (right). Circuit diagram for the Rain Alarm. Produced using Circuit Wizard

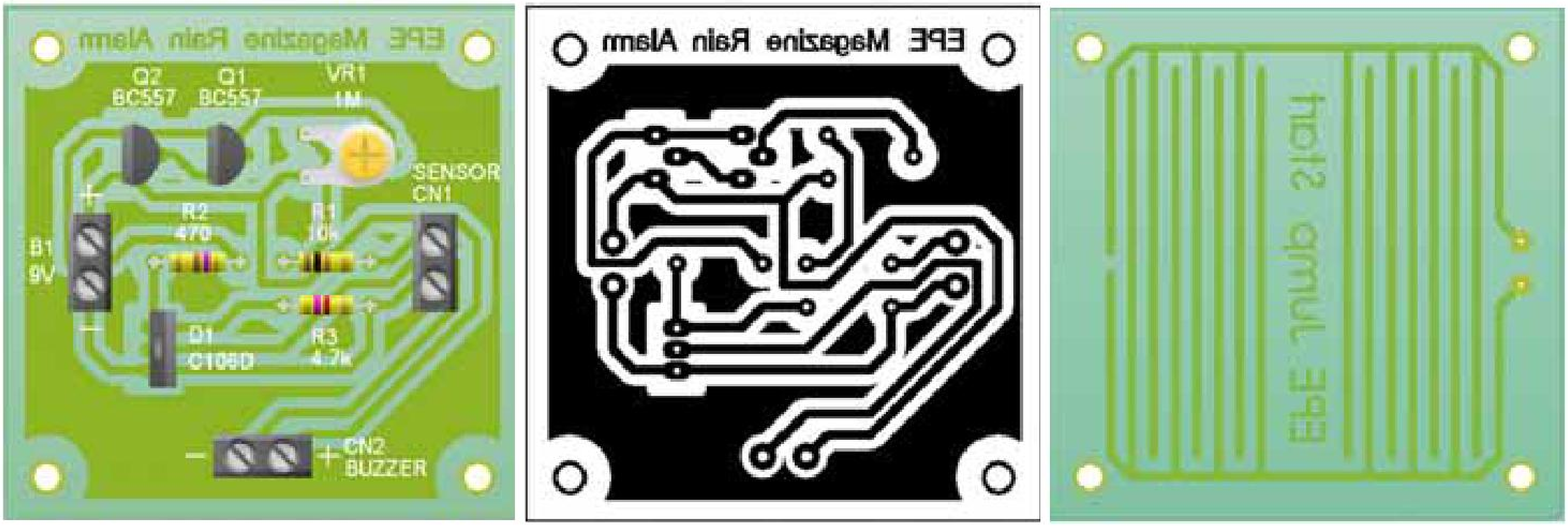
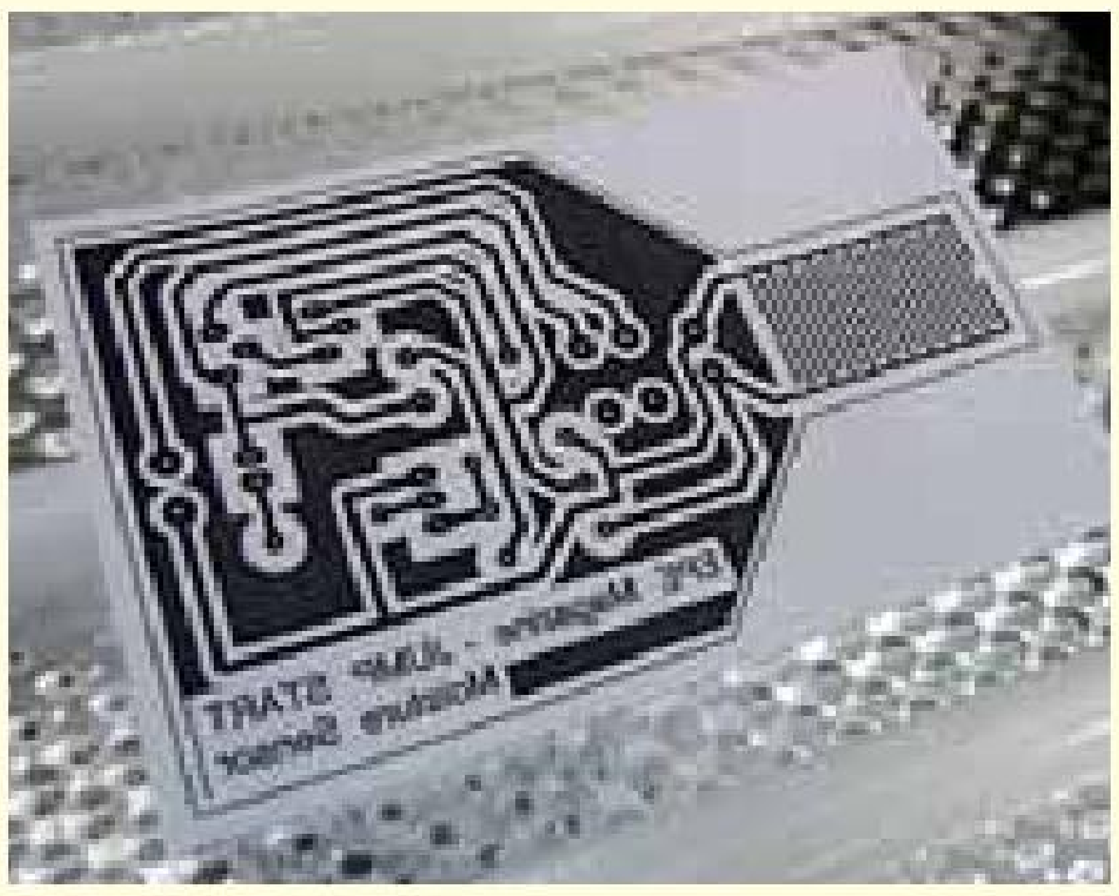

EPE Magazine Rain Alarm
Q2
BC557
Q1
BC557
VR1
1M
SENSOR
CN1
+
B1
9V
R2
470
R1
10k
–
D1
C106D
R3
4.7k
–
+
CN2
BUZZER
EPE Magazine Rain Alarm
EPE Jump Start

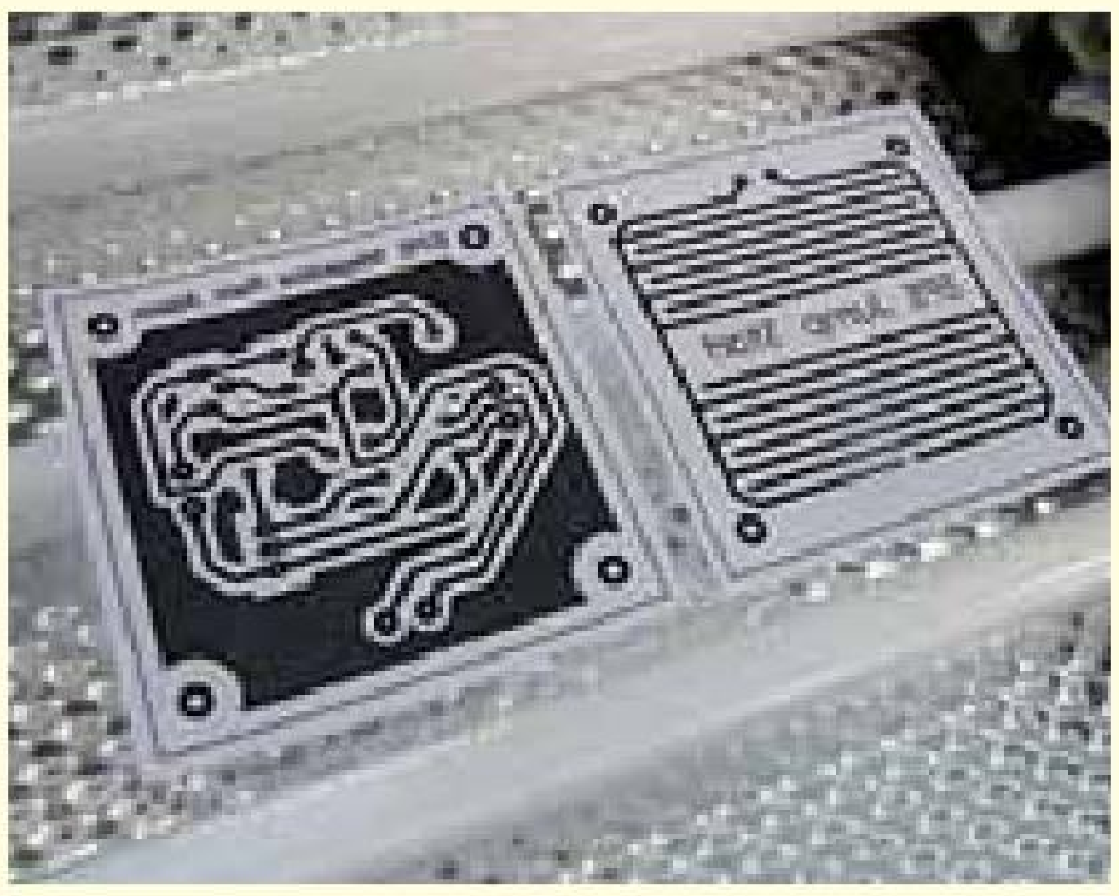
Fig.14. Main PCB, copper track artwork, and sensor board produced by Circuit Wizard for the Rain Alarm

Photo gallery...

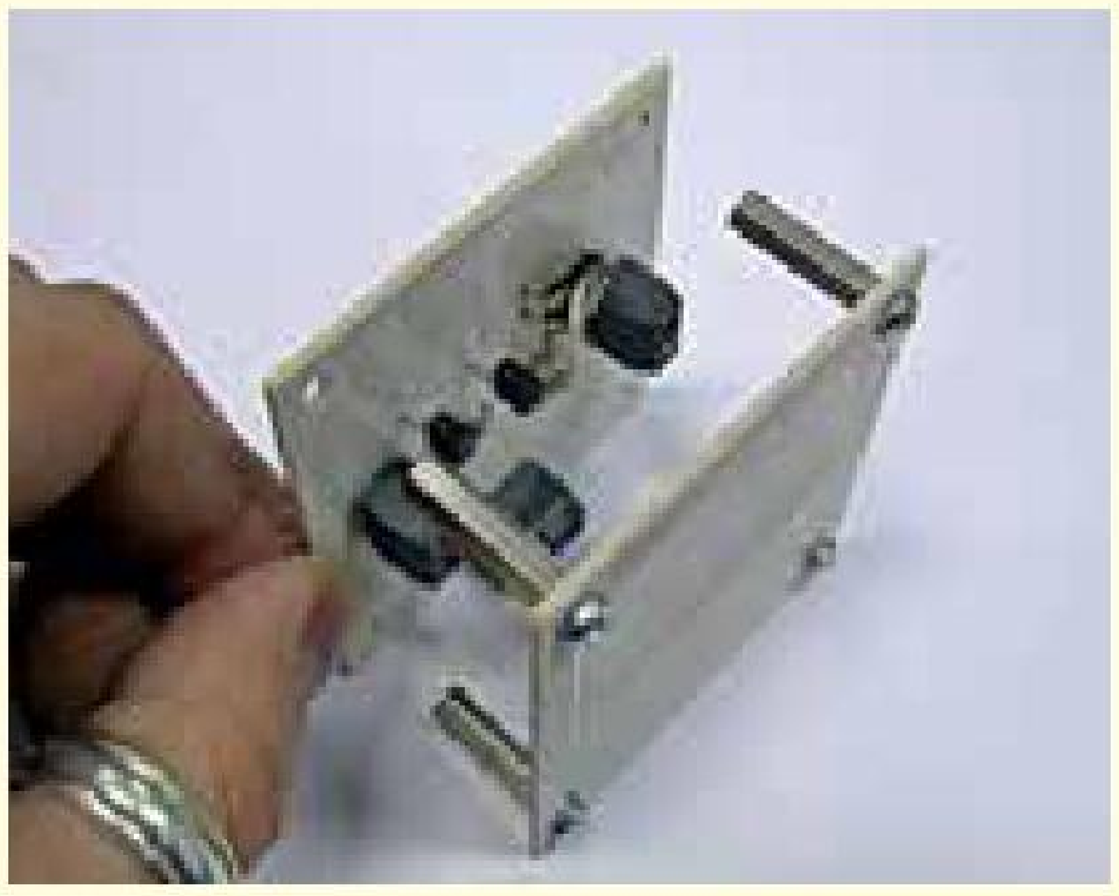


Printed circuit template for the Plant Pot Moisture Sensor

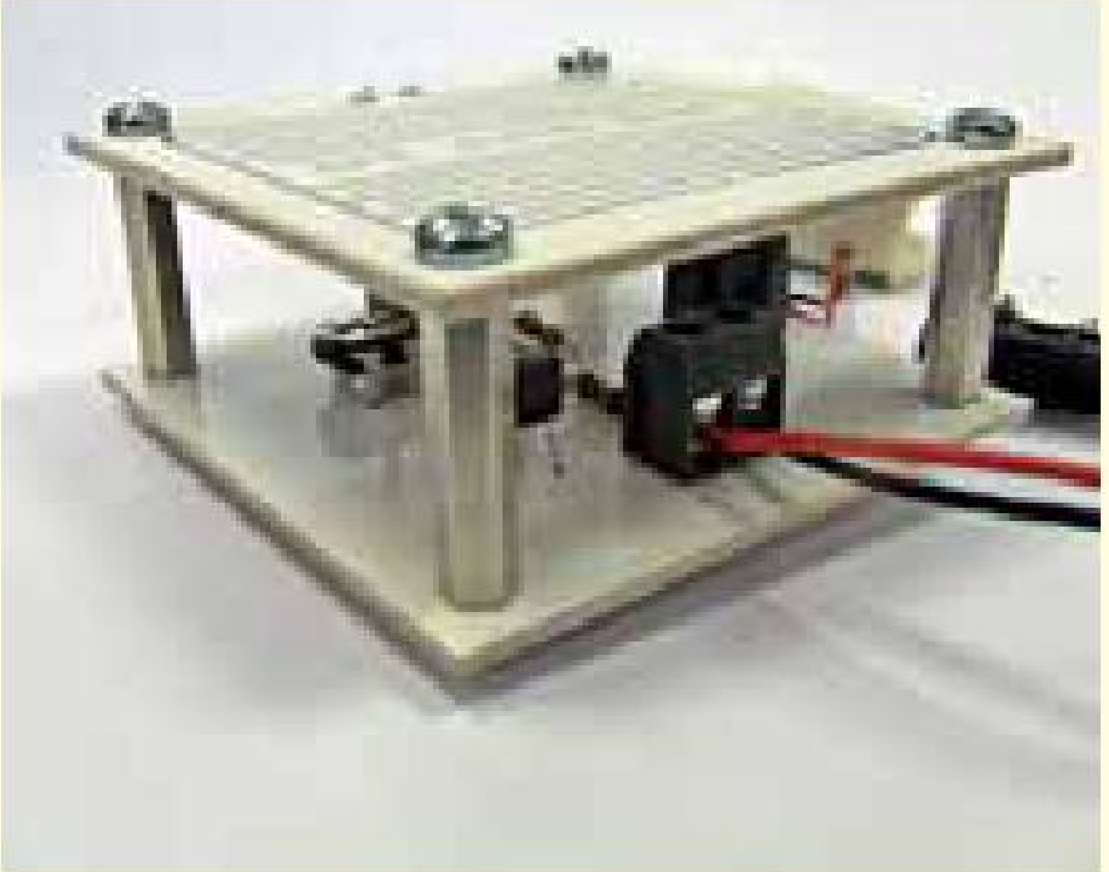
Photo etch PCBs ready for etching



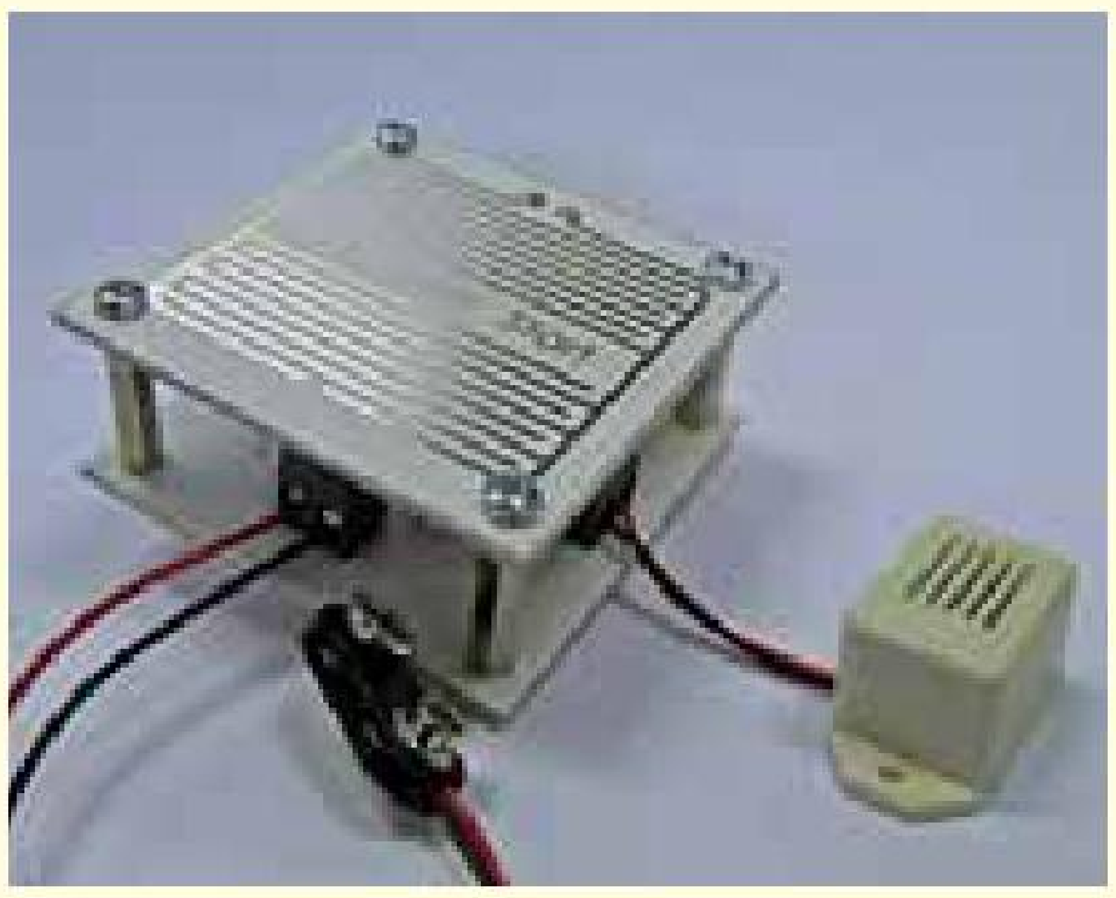
Printed circuit templates for the Rain Alarm



Assembling the main and sensor PCBs for the Rain Alarm



Off-board wiring is made to the terminal blocks on the main Rain Alarm PCB



The completed Rain Alarm ready for deployment

Next month

In preparation for the summer exam season, our next *Jump Start* features a Simple Quiz Machine. See you next month!

Special thanks to Chichester College *for the use of their facilities when preparing the featured circuits.*

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REGULAR CLINIC BY IAN BELL

Triac driving

EPE *Chat Zone* contributor ***echase*** posted to ask about triac driving.

What is best way to run a 20A or 30A triac from a PIC? Logic-level triacs seem to be limited to 10A.

In the absence of better advice, I guess an optotriac driving the 20A triac is the solution. Is there a cheaper/lower component count solution, as I don't necessarily need to isolate the mains from the PIC in this case.

Triacs are a member of a family of devices that also includes diacs, silicon-controlled rectifiers (SCRs), and various more exotic components such as MOS thyristors. The circuit symbols for an SCR, diac and a triac is shown in Fig.1.

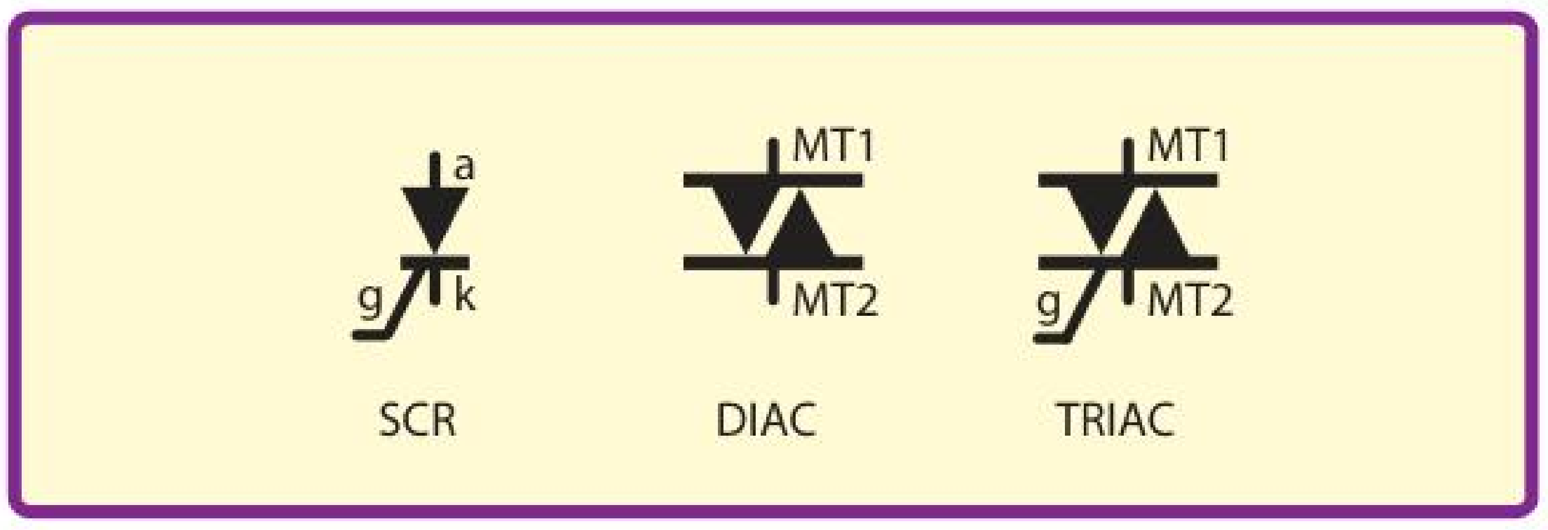


Fig.1. Symbols for SCR, Diac and Triac

Operation

All these devices are bistable, that is, they have two states of operation, with different levels of conductivity between the main terminals in the two states. In the 'on' state they have low impedance, which is maintained as long as the current through the main terminals remains above a certain limit known as the 'holding current'. In the 'off' state they have very high impedance, which is maintained as long as the applied voltage is below a certain limit known as the forward breakover , or breakdown voltage.

Some of these devices, such as SCRs, conduct in one direction and behave as reverse biased diodes in the other direction. As for these devices, the main terminals are designated as anode (a) and cathode (k). Other devices, such as diacs and triacs, conduct in both directions, here the main terminals are simply called main terminal 1 (MT1) and main terminal 2 (MT2).

Some of these devices, such as the SCR and triac, have a third terminal known as a gate (g). The higher the current into the gate, the smaller the forward breakover voltage becomes. Thus, applying a sufficient pulse of current to the gate will switch the device into the on state. Once in the on state, the gate current need not be maintained due to the bistable action mentioned earlier. The device remains on until the main current falls below the holding current.

A current plot

The bistable action of these devices means that plots of current against voltage look a little odd. Fig.2 shows a graph of current against voltage for a diac. For comparison, the plots of a low-value and a high-value resistor are also shown. Notice how the diac switches from high resistance to low resistance when the breakover voltage is reached.

All these devices are based on at least four alternating layers of *p* and *n* silicon, with at least three diode junctions. Fig.3 shows the structure of an SCR constructed from four layers of silicon of alternating type (ie, *pnpn* (*p* and *n* type semiconductor)). Compare this with a bipolar junction transistor (BJT) which is three-layer – either *pnp* or *npn*. The SCR is like two overlapping transistors – the *np* of a *pnp* transistor overlapping the *np* of an *npn* type, as indicated by the dotted boxed in Fig.3a. This leads to the transistor equivalent circuit in Fig.3b.

We can understand this behaviour by looking at the equivalent circuit of the SCR in Fig.3b. The 'trigger' gate current turns on transistor TR1. The collector current of TR1 provides a base current for TR2, turning it on too. In a similar manner, the collector current of TR2 provides more base current for TR1, turning it on even more. This is a positive feedback effect that quickly ensures that both transistors are on.

Once this condition has been triggered by the gate it is self-sustaining, so gate current is no longer needed. If the voltage between anode and cathode is increased to the breakover point, the currents within the device are sufficient to switch it on without any additional current from the gate.

The triac is a little like two back-to-back SCRs (but this analogy is only approximate). It conducts in both directions and can also be switched on by a gate current of either polarity. In comparison, an SCR conducts in only one direction, and the trigger current can only flow one way too. The diac is

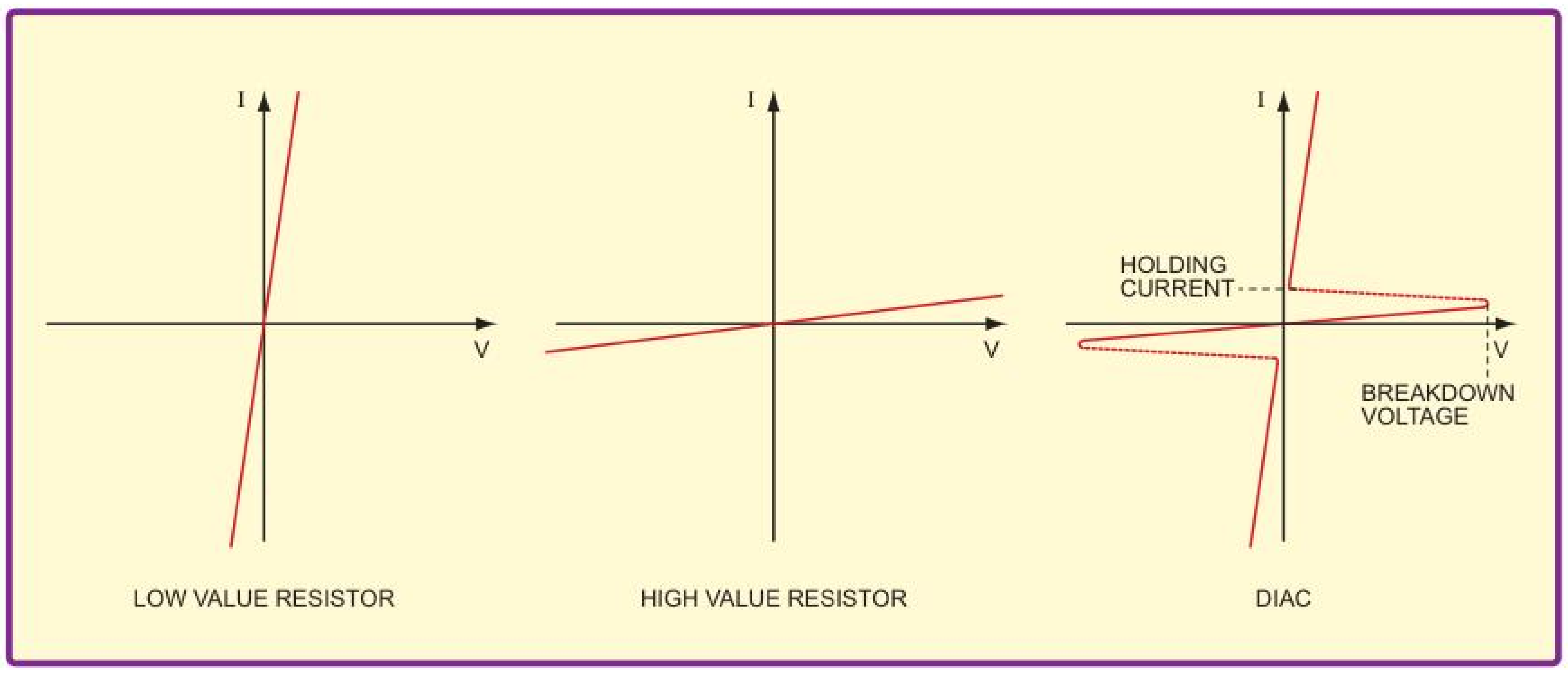


Fig.2. Plots of current against voltage for low value resistor, high value resistor and diac

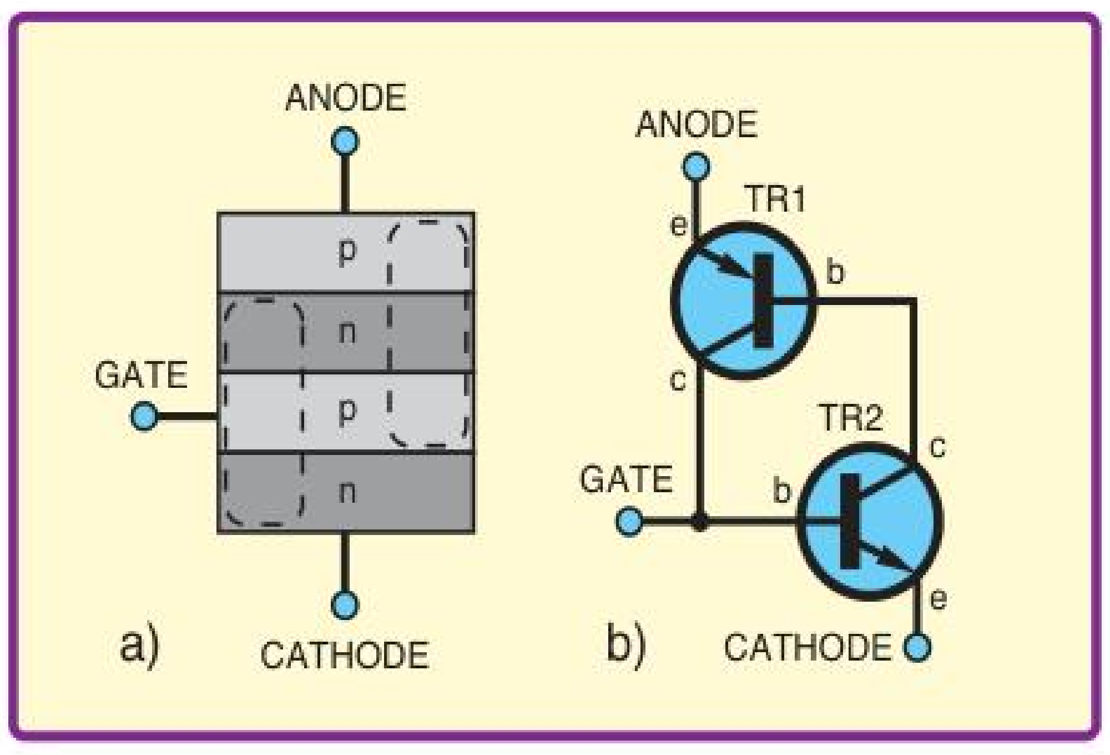


Fig.3. Silicon controlled rectifier (SCR) physical structure (a), and equivalent transistor circuit (b)

like a triac without the gate connection. It is switched on by applying a voltage above the breakover voltage in either direction. The bidirectional nature of diac and triac operation means that they can be used to switch AC, whereas SCRs can only be used for DC or one half of an AC waveform. Triacs are often used for AC mains power control and switching.

Lamp dimmer

One of the most well known applications of triacs and diacs is in dimmer circuits for incandescent lamps. An outline of a dimmer circuit is shown in Fig.4. The triac is switched on part way through each half cycle of the mains waveform, and hence supplies power to the lamp. The triac will switch off as the waveform crosses through 0V because the current in the device will fall below the holding current.

During each half cycle of the mains waveform the capacitor charges up at a rate set by the variable resistor (potentiometer). When the voltage on the capacitor reaches the breakover volatage of the diac it will switch on sending a pulse of current into the triac.

The triac, and hence the lamp, will switch on and remain on until the mains waveform crosses through 0V again. The triac's breakover voltage will be higher than the peak mains voltage (a typical value would be 500V) so it will not switch on by this mechanism, only by the gate current via the diac.

The diac's breakover voltage will be much lower than the mains peak voltage, a typical value would be around 30V. Thus, the earlier in each half cycle the triac is switched on the greater the proportion of time the lamp will be on and hence the brighter it will shine.

This circuit (Fig.4) is for illustration only, as it lacks important features such as RF suppression, diac current limiting, and snubbing, and has relatively poor control, particularly at low power levels. Additional circuitry is needed for acceptable performance.

The simple lamp dimmer does not have a digital control circuit, but we assume echase requires digital control as he is asking about logic-level triacs and PIC microcontrollers. Fig.5 shows the basic idea, in this case with an SCR. The digital control circuit provides the gate current to turn on the SCR and hence the load.

Snubber

The gate current is, unfortunately, not the only way to turn on an SCR or triac. A sufficiently fast rising anode-cathode voltage can also do so, due to the capacitances inherent in the SCR's structure. To prevent this, snubber circuits can be used to reduce the rise-time of voltages across the SCR, as shown in Fig.6. Snubbers (across MT1 and MT2) should also be used where appropriate with triacs.

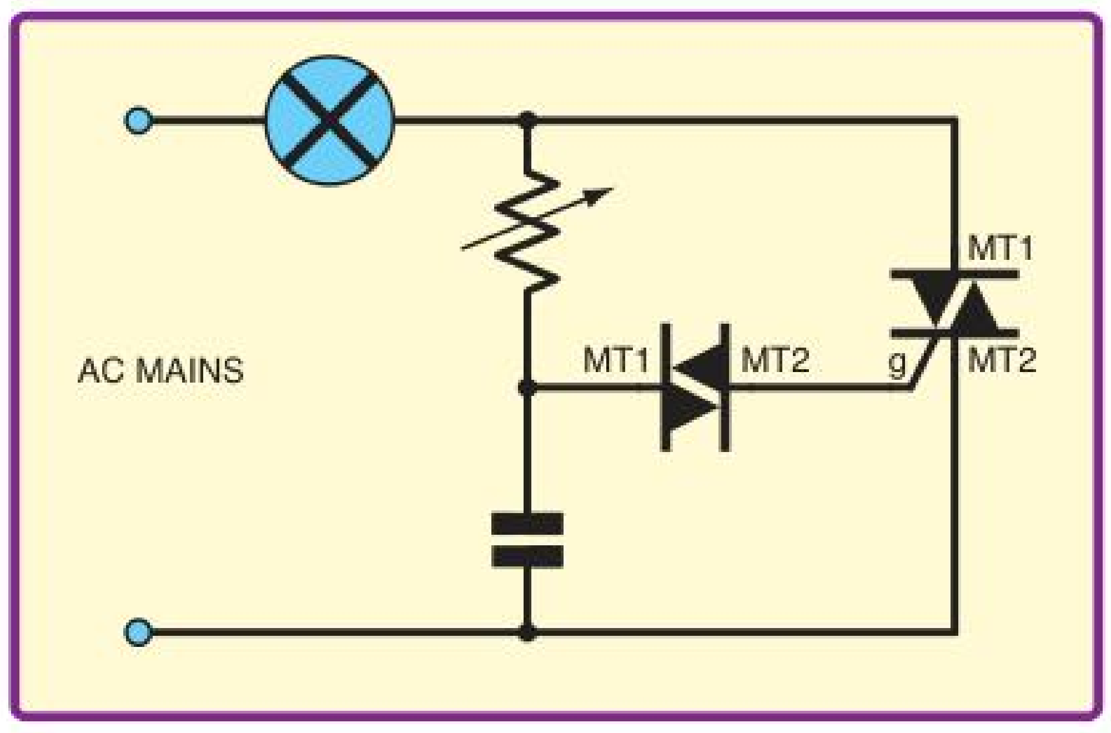


Fig.4. Lamp dimmer concept (not a practical circuit)

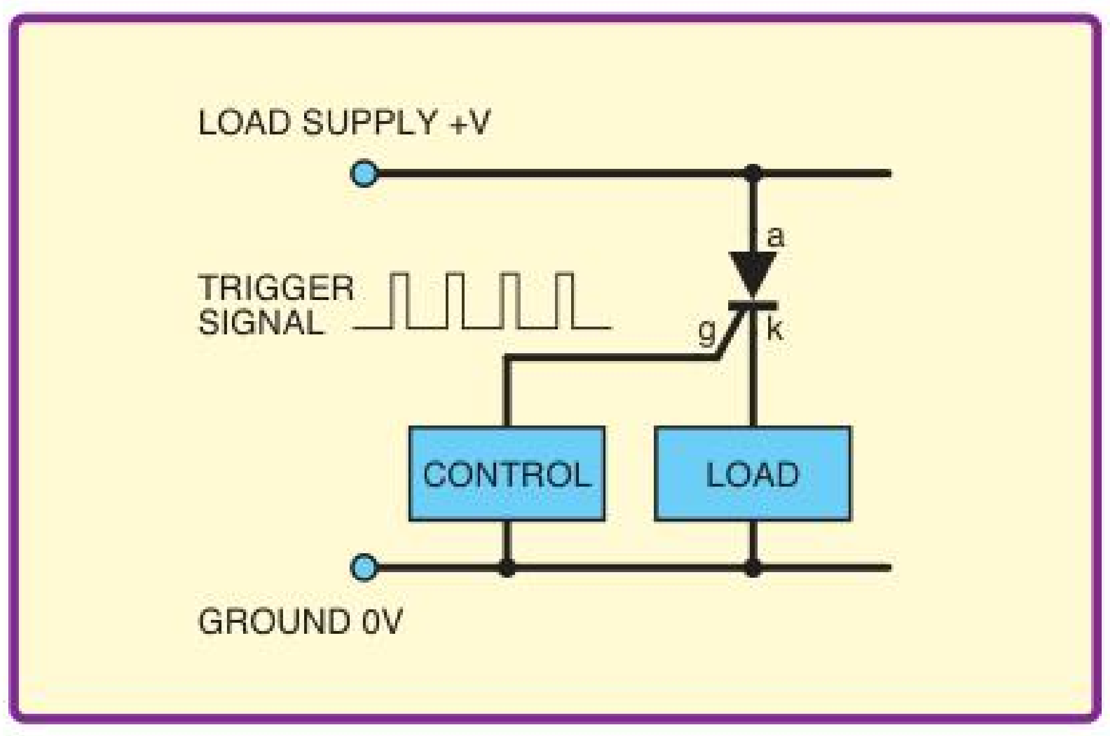


Fig.5. Basic SCR control circuit

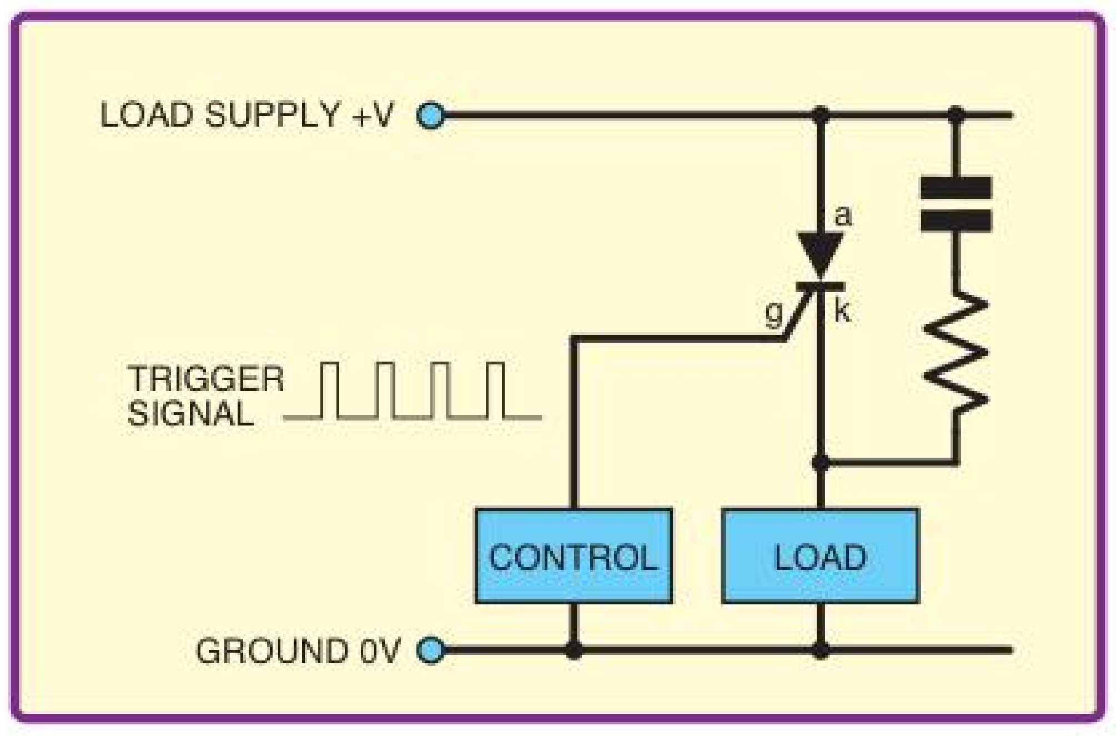


Fig.6. Thyristor SCR circuit with snubber to prevent false triggering

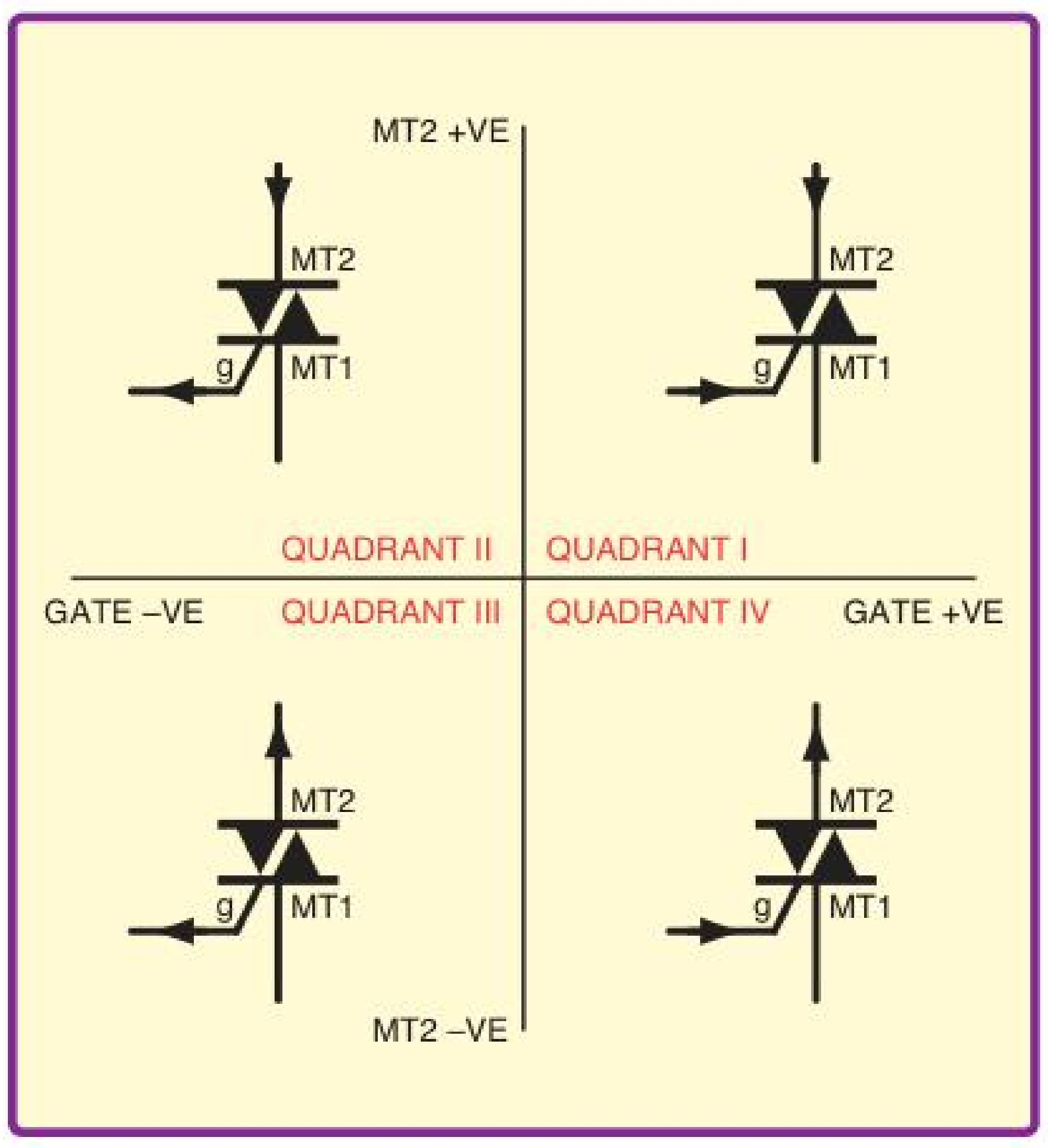


Fig.7. Four possible triac triggering scenarios, or quadrants

Typically, the control circuit will be a microcontroller such as a PIC. In principle, the circuit in Fig.5 could also be used to switch a triac, but usually we are switching AC mains voltages with triacs and this leads to a requirement for a separate low voltage DC supply for the digital circuit. Before discussing how we can arrange this, we will look at triac switching in a little more detail.

Triac switching

The fact that triacs can conduct in both directions and can be triggered by gate currents of either polarity leads to four possible triggering scenarios, or quadrants, as illustrated in Fig.7. Positive half cycles of the AC waveform correspond to quadrants I and II in the upper half of Fig.7. The triac's MT2 terminal is positive with respect to MT1. Negative half cycles of the AC waveform correspond to quadrants III and IV in the lower half of Fig.7. The triac's MT2 terminal is positive with respect to MT1.

Situations where the trigger circuit is sinking current – so that the trigger current flows out of the gate (negative gate current) correspond to quadrants II and III on the left half of Fig.7. Situations where the trigger circuit is sourcing current – so that the trigger current flows into the gate (positive gate current) correspond to quadrants I and IV on the right half of Fig.7.

Triacs are typically most sensitive (require lower trigger currents) in quadrants I and III. They are slightly less sensitive in quadrant II and least sensitive in quadrant IV. Some triacs cannot be triggered in quadrant IV. Datasheets typically refer to 'four quadrant' and 'three quadrant' triacs to indicate whether or not the device will switch in quadrant IV.

Three quadrant triacs are typically trading off this gate trigger option against reduced sensitivity to triggering by rapidly changing main terminal voltage. A certain rate of change of voltage (dV/dt) may trigger the triac without a gate trigger being applied. As was mentioned earlier, this may require a snubber network to protect the triac.

False triggering

There are a couple of scenarios in which high rates of change of terminal voltage may inadvertently trigger the triac. The first is simply by applying a fast changing voltage to the main terminals and is referred to as 'static dV/dt'.

The second scenario occurs when the triac tries to turn off with an inductive load. The resulting voltage spike from the inductor may cause the triac to turn back on again. This is referred to as 'commutating dV/dt'. Commutating dV/dt is less than static dV/dt and therefore is more likely to cause difficulties.

Making a triac less sensitive to fast voltage changes may mean that the snubber is not required, reducing component costs. Such devices are marketed as 'Snubberless triacs', or 'Alternistors' or high commutating triacs. ST Microelectronics are a key company in this area. Loss of fourth quadrant triggering in these devices is not a major problem because most triac circuits do not use triggering in the fourth quadrant anyway.

When used to switch AC, a triac will switch off at the end of the half cycle during which it was triggered – this is because the current through the device will drop below the holding current as the AC voltage drops towards 0V. Thus, to switch a load on continuously a triac has to be triggered in every half cycle of the AC waveform.

Digital control

The classic lamp dimmer in Fig.4 triggers the triac automatically every half cycle because the diac triggers in each half cycle once the voltage is large enough. However, a digital control circuit may have to monitor the AC waveform in order to know when to apply the trigger pulses. Usually, this takes the form of zero crossing detection. The control circuit detects the point at which the mains crosses 0V and uses this as a reference point for trigger timing.

Triacs are often used in power control (as in the lamp dimmer) by manipulating the point in the AC half cycle at which the device is triggered (known as phase control). The later the power is switched on the less power is delivered to the load.

As indicated, triacs are triggered by current not voltage. This is convenient for logic control because it means that logic voltage levels do not need to be matched. The term 'logic-level triacs' therefore refers to triacs with gate trigger currents within the range of typical digital circuits, particularly microcontrollers.

This usually means less than about 20mA or 25mA (note that a typical PIC can sink about 25mA) and typical logic level triacs requires gate currents of 10mA or less. The term 'sensitive gate triac' is also used for devices which can be driven directly from logic circuits.

The trigger current required by a triac increases as the switched current increases. This is why echase is having difficulty finding logic-level triacs to switch 30A. Triacs with current handling of 10A to 40A typically need gate currents of 50mA to 100mA, depending on device current and triggering quadrant.

Where the digital circuit has insufficient current capability, the triac can be switched via a suitable transistor. Alternatively, where supported by the digital device, outputs from the controller may be driven in parallel to increase current drive capability to a level required to trigger the triac.

The gate current must be applied for sufficient time to turn on the triac. This 'turn-on time' will be specified in the datasheet and will typically be in the order of microseconds. The specified time will assume a large voltage across the triac, but if the trigger pulse is applied early in the AC cycle, it may have to be held for longer to ensure that the triac is conducting above the holding current before the trigger is removed.

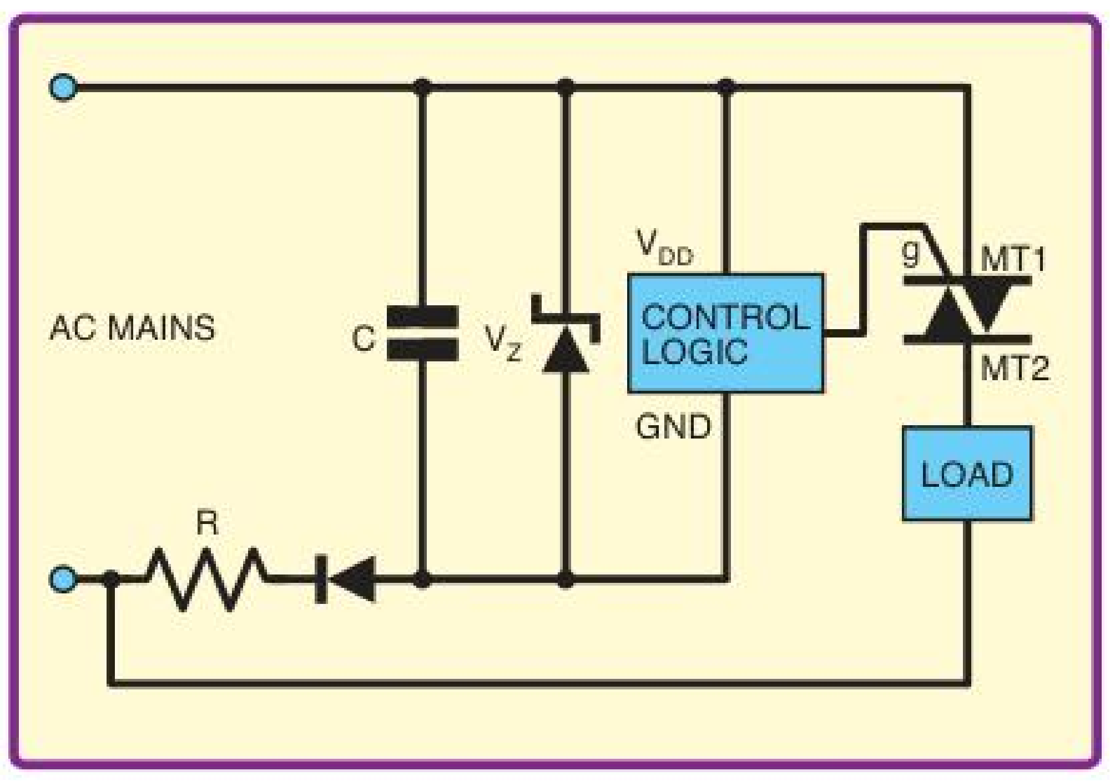


Fig.8. Transformerless power supply for triac control. Design concept – this is not a practical circuit! (see text)

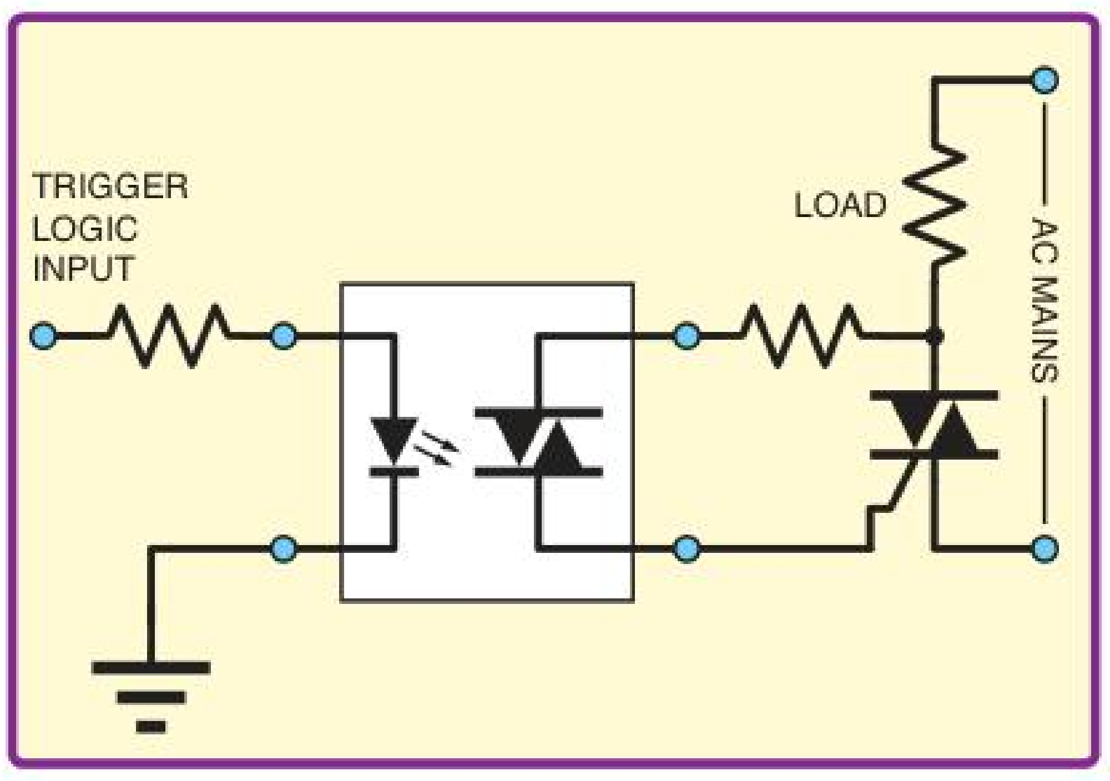


Fig.9. Optoisolated triac control

Fig.8 and Fig.9 show a couple of widely used approaches to driving triacs from digital circuits such as microcontrollers. The circuit in Fig.8 provides a power supply to the microcontroller without use of a transformer or switching regulator. It is a very low cost approach and is widely used in domestic appliances. The microcontroller supply 'hangs' off the mains supply. There are a number of similar circuits based on this general concept.

The microcontroller supply is provided by a capacitor (typically a few hundred microfarads) which is charged to a voltage limited by a Zener diode (typically 5.1V or 5.6V). A diode ensures that the charging current is of the right polarity (in one half of the mains cycle). A resistor limits the current (typically a couple of kilohms and a few watts rating). In addition, safety and electromagnetic interference (EMI) protection components (not shown in Fig.8) are required.

The microcontroller can easily switch the triac gate from a voltage equal to MT1 (zero gate current) to a voltage V_{DD} volts below the MT1 voltage, which causes a negative gate current. This can happen at any point on the mains cycle because the logic ground (Gnd on Fig.8) is always V_{DD} volts below the mains line. Thus, this circuit triggers the triac in quadrants II and III.

The circuit is Fig.8 can only supply a relatively low continuous current to the control logic (a few tens of mA) but may be able to provide larger currents for the short duration required to trigger the triac. If the microntroller cannot switch the trigger current directly, an external transistor can be used.

The circuit in Fig.8 potentially provides the cheap solution echase was asking about (with a transistor to boost drive current). However, **extreme care** must be taken when working with circuits like that in Fig.8 due to the risk of lethal shock. There is also a potential risk to the PC and microcontroller programmer during development. The mains MUST be disconnected when programming the controller.

The circuit in Fig.8 is not suitable for building as shown – it is just a concept circuit. Component values must be carefully calculated and additional safety features added. Work on such a circuit should only be attempted by someone with significant experience of both working with mains voltages and microcontroller programming.

Opto control

In situations where low cost is not such a driving factor, and where having a controller connected directly to the mains is unsafe, an optoisolated triac trigger, as shown in Fig.9, is preferable. Here the microcontroller or other logic circuit runs from a conventional low voltage power supply.

The optoisolator keeps the triac/load and control circuit electrically separate, and so we do not have to worry about any interaction between them (relative voltage levels etc) during design. In use, the operator of the controller is also isolated from the mains (assuming safe construction is used). The circuit in Fig.9, like the classic dimmer in Fig.4, triggers the triac in quadrants I and III.

The optotoisolator comprises an LED and detector in a single package. Switching on the LED causes light to fall on the detector, switching it on, which in turn triggers the triac. The detector is a complex device which behaves like a diac/triac triggered by light. In some optoisolators, further control circuits are present, which ensure switching close to the zero crossing of the mains waveform. This reduces surge currents to the load and decreases the EMI due to load switching.

Optoisolator traic drivers, which can switch at any point on the mains cycle, are called random phase drivers. A variety of optoisolated triac drivers are available, such as the MOC30XX family of random phase drivers from Fairchild Semiconductor. Drive capabilities of optotoisolator traic drivers are sufficient to trigger higher current triacs and therefore provide a viable solution as requested by echase as part of his question.

Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

ACCORDING to the old saying 'you shouldn't judge a book by its cover', but I suppose that in the real world most people do tend to judge things by their appearance. This probably applies to home constructed electronic projects as much as anything else.

Making your latest electronic masterpiece look really good with a professional quality front panel overlay will not make it work any better, but it will certainly make it more impressive when you show it to your friends and family. Being purely practical about matters, a gadget that is neatly labelled will be easier to use than one that lacks any panel legends, especially when the gadget in question has numerous controls.

Days gone by

In days gone by, the usual method of making a front panel overlay was to use a photographic technique. A more simple approach was to label the panel using rub-on lettering. Unfortunately, the 'gone' part of 'days gone by' now very definitely applies, and obtaining the materials needed for the traditional approaches to front panel labelling seems to be practically impossible.

Many of the manufacturers of these materials have either ceased trading or moved on to other things. It is still possible to obtain rub-on lettering, but sources of supply are few and far between, the choice of sizes and styles is much more restricted than it used to be, and prices tend to be quite high.

The gradual demise of traditional graphic arts materials is due to professional and amateur users moving to computer-based systems. The traditional approach to labelling panels is still possible, and it might be a worthwhile proposition if you do not have access to computer equipment. It is otherwise probably not worth considering.

Got it taped

Even if you do not have access to suitable computer equipment, a small electronic labelling machine might offer a better alternative. These use self-adhesive tapes, and most can accommodate tapes of two or three different widths. In the current context it is the narrower (3.5mm to 12mm) tapes that are of most use. Tapes are available with various combinations of foreground and background colour.

The characters are produced using a simple thermal/dot-matrix system, but the quality is quite good. The edges of some characters are slightly rough when examined closely (Fig.2), but in normal use this is not something that anyone is likely to notice.

If you can find a good deal on a small electronic labeller and some tapes it will probably cost less than an assortment of good quality rub-on lettering, and will produce far more labels. A labeller provides a much quicker and easier way of doing things. The labels produced are much tougher than those produced using rub-on lettering, and will normally last for years without the need for any protective coating.

The adhesive used for the labels is quite strong, sticks instantly, and seems to be very durable. This is good in that it provides permanence, but the downside is that it does not permit labels to be slid into precisely the right position. Even sliding a label by a millimetre is not usually possible. It helps if you can get it right

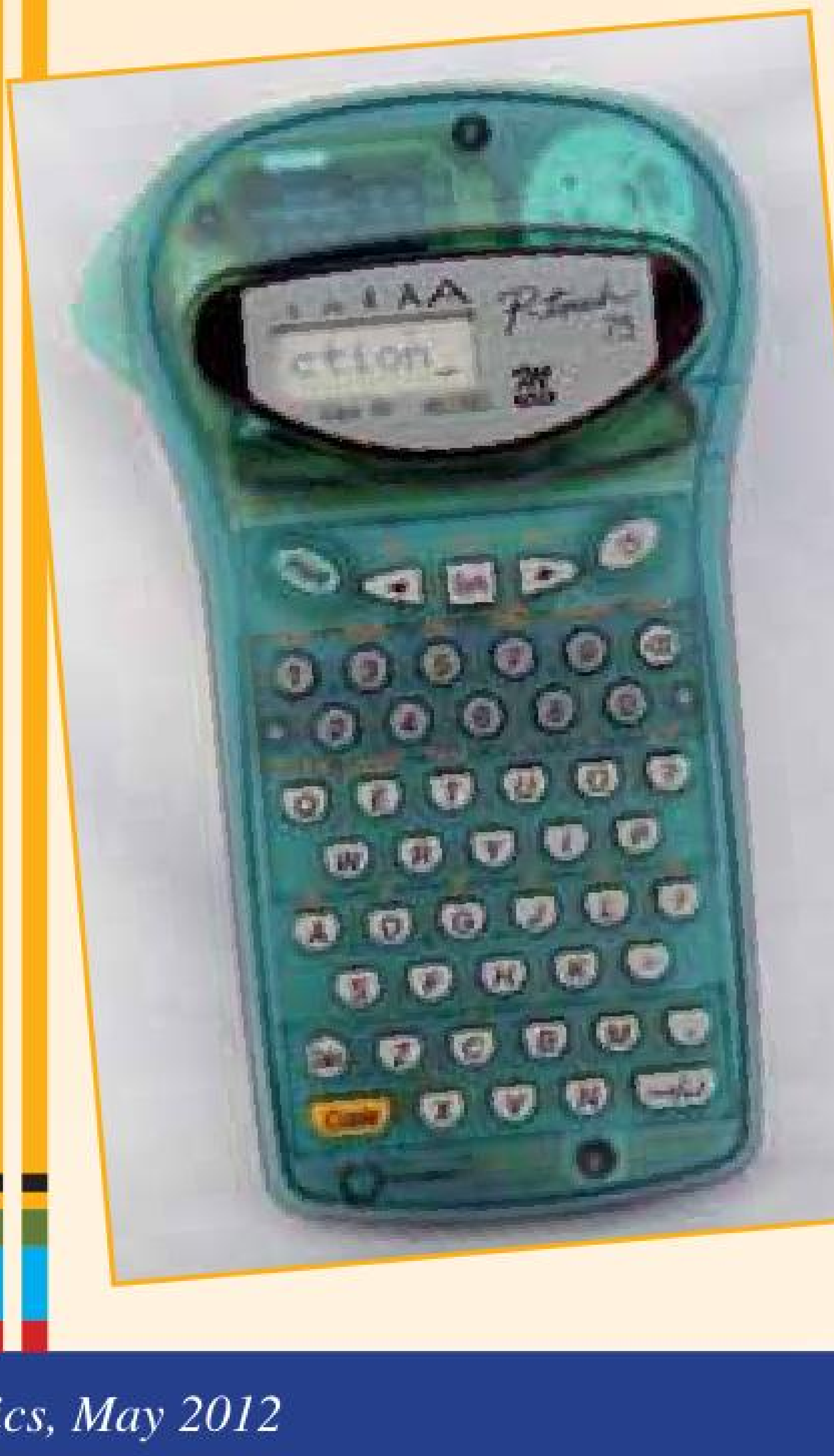
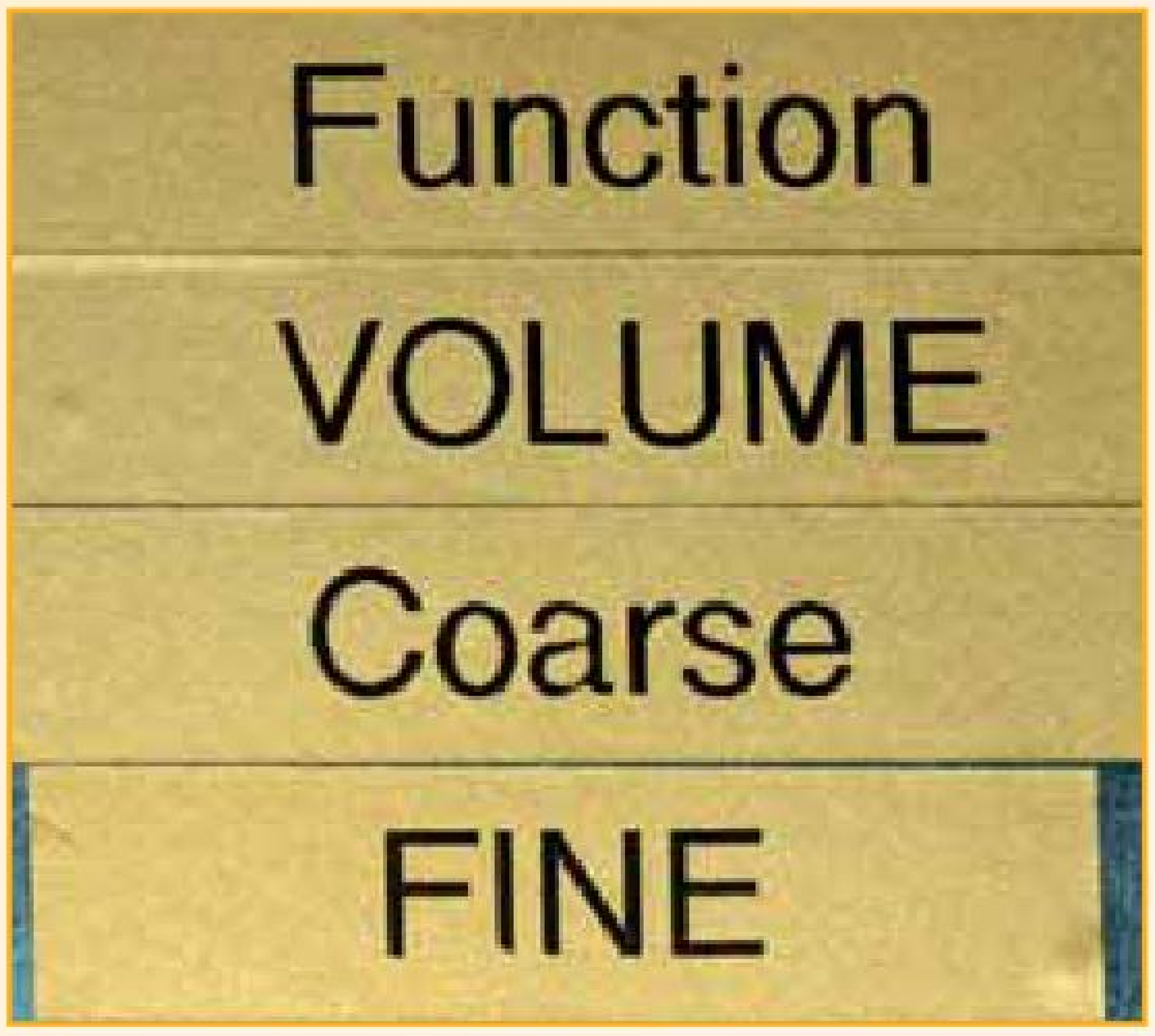


Fig.1 (left). A small handheld electronic labeller such as this probably represents the quickest and easiest way of producing labels for projects. Tapes in various widths and colour combinations can be obtained

Fig.2. The labels below are produced using a form of dot matrix printing. This can produce some slightly rough edges, but in use these are not normally noticeable and the quality is quite reasonable



first time, but it is usually possible to carefully peel a label off and try again, provided it has not been fully pressed down and into place. It is not the end of the world if a label becomes damaged when it is being peeled off. A replacement can be printed almost instantly and at an insignificant cost.

Cutting back

Most electronic labellers use relatively wide tapes, and consequently produce lettering that is often a bit larger than would be ideal. For the present application, it is advisable to choose one that can handle very narrow tapes. Even when using a narrow tape, it is quite likely that the labels will still be too large for small gadgets.

However, most labellers seem to leave a fairly large blank area around the lettering. The actual height of the text tends to be much less than the width of the tape. If there is an option to print smaller text, using it will produce an even larger blank surround.

Even where there is plenty of space for the raw labels, they tend to look 'not quite right' when used with anything other than the largest of projects. Trimming the edges of labels slightly in order to produce something that gives a better appearance can be rather fiddly. This is especially so with the tapes having a width of 6mm or less. However, with due care it can be done using a sharp modelling knife, a cutting mat, and a metal ruler. Paper trimmers are intended for cutting large sheets of paper, but a good one provides an easy and relatively safe means of trimming labels.

When individual labels are used, it can be helpful to mark guide lines or use tape to provide a guide that will make it easier to get a row of labels aligned accurately. This applies regardless of the method used to produce the labels. Obviously, the guide lines must be marked using a method that makes them reasonably easy to remove.

Front panels are often made from relatively soft materials such as aluminium or plastic, and care must be taken not to scratch and permanently mark panels. Be careful when using spirit-based inks on plastic. There is a risk of the ink dissolving and permanently marking the plastic. It is a good idea to test pens and other marking tools on the inside of the case where any damage caused will be out of sight.

Computer labels

Producing simple labels using a computer and a printer is very easy, and it does not really require any special software. Any modern word processor should be able to produce lettering in a wide variety of fonts, styles (bold, italic), sizes, and colours. WordPad, the simple word processor that comes as part of a standard Windows installation, is certainly capable of doing all this.

A word processor is adequate where straightforward labels are involved, with no fancy tricks such as varying the size of text within a label. More complex labels require a suitable graphics program, as does the production of front panel overlays. In the case of the latter, it is necessary to produce accurate designs that when printed out will precisely fit the front panels. Programs produced for professional graphics designers are ideal for this type of thing, as are modern CAD (computer aided design) programs. Unfortunately, programs such as Adobe Illustrator and AutoCAD are too expensive for most hobbyists.

There are low cost and even free alternatives, which although lacking the vast range of features provided by the upmarket alternatives, have sufficient features and are reasonably easy to learn. Serif DrawPlus used to be a popular choice, but the free version lagged behind the times and would not always run reliably on modern PCs. However, there is now an updated version called DrawPlus Starter Edition that runs quite happily on systems running Windows XP, Vista, or 7, and the hardware requirements are quite modest.

There is no time restriction on the use of the free version, and it is possible to save and print the drawings produced. Some of the more advanced features of the full program are not available in the Starter edition though. Nevertheless, the free version does have the facilities needed to produce fancy labels (Fig.3) or even a full front panel design. There are all the usual facilities for choosing the required font, colour, style, and text size, but even a simple vector drawing program should go somewhat further.

In the case of DrawPlus Starter Edition, there are facilities for skewing text, rotating it at any angle, stretching and compressing it, moving individual letters, mirroring it, and using fancy fills instead of the same colour throughout. The fills available include various patterns, plus gradients such as linear radial, elliptical, and conical types. It is even possible to use complex gradients that have multiple colours.

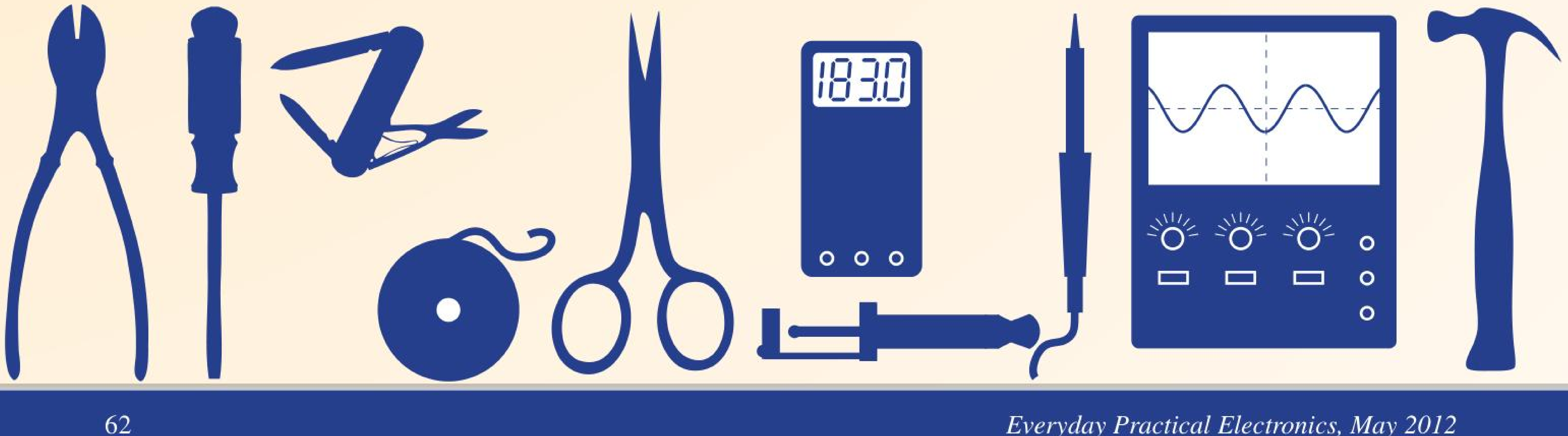
Path way

An advanced feature for a free program is the ability to have text follow a path. The path is a shape drawn on the screen, but the shape does not have to appear in the final design. If required, it can be hidden from view and just used as a guide for the text to follow. In the example of Fig.3, the word 'TEMPERATURE' near the bottom left-hand corner of the screen has been fitted to a path provided by the top section of a circle, although in this case the circle is not visible on the screen.

A facility such as this, in conjunction with the ability to rotate text, can be useful for producing dials. A good 2D CAD program is probably the best choice for producing accurate dials, but the commercial programs of this type are quite expensive, and the free CAD programs I have tried lack the facilities to make a really good job of this type of thing. DrawPlus Starter Edition can do the job quite well though, and is probably more than sufficient for most purposes.

The fills available for text can also be used with shapes such as circles and rectangles, which can be very useful. For example, when producing a panel overlay you can draw a rectangle to represent the front panel, and then add a fill such as a pale tint rather than just accepting the raw colour of the printing paper. Taking things a stage further, a gentle linear gradient could be used, or for a suitably zany project, a multi-coloured gradient fill could be applied.

The next step is to add circles to represent the holes in the panel, and



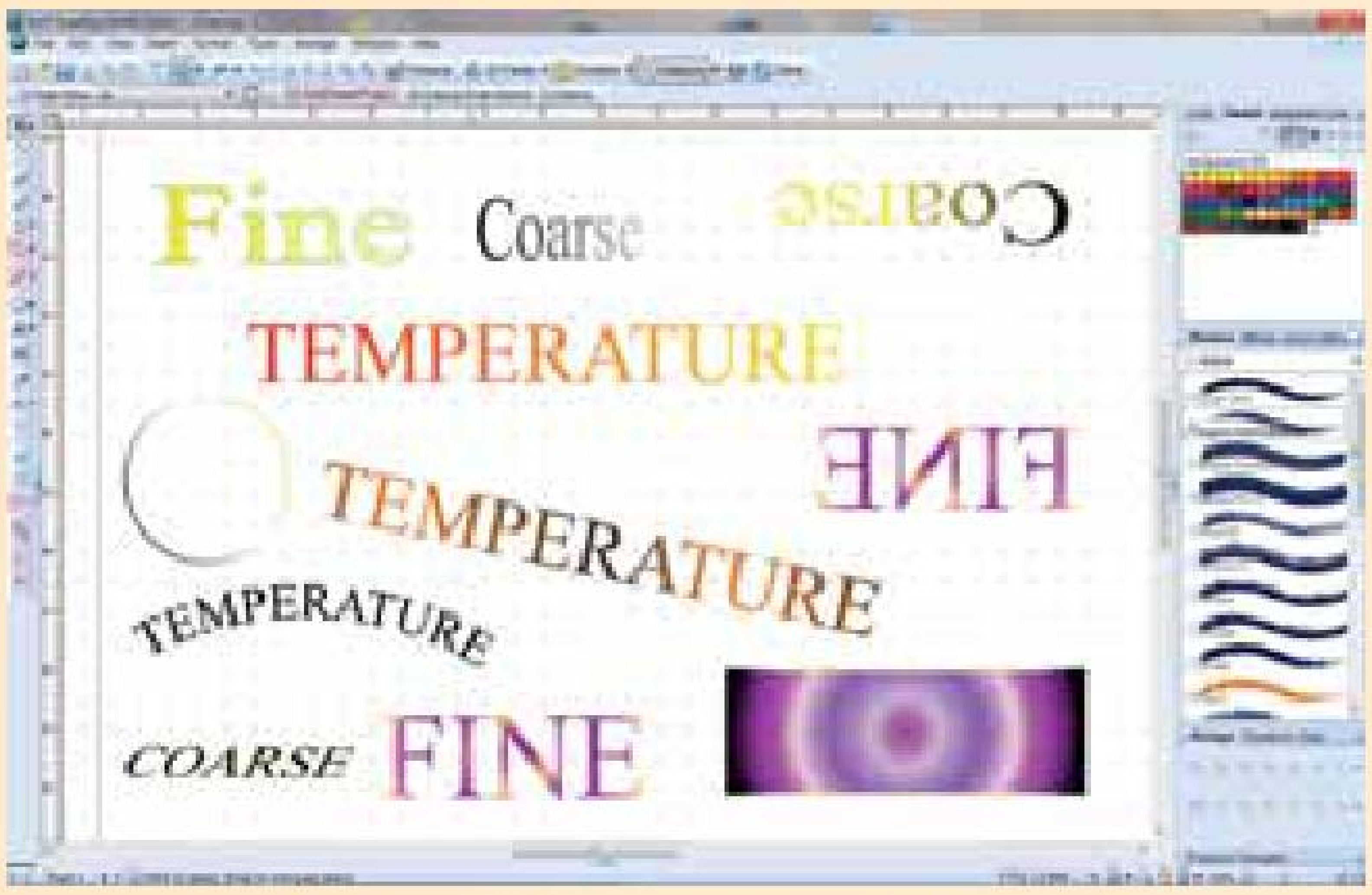


Fig.3. A vector graphics program such as DrawPlus Starter Edition goes beyond the basic text effects available in a word processor. Among other things, text can be stretched, compressed, skewed, mirrored, rotated, and given fancy fills

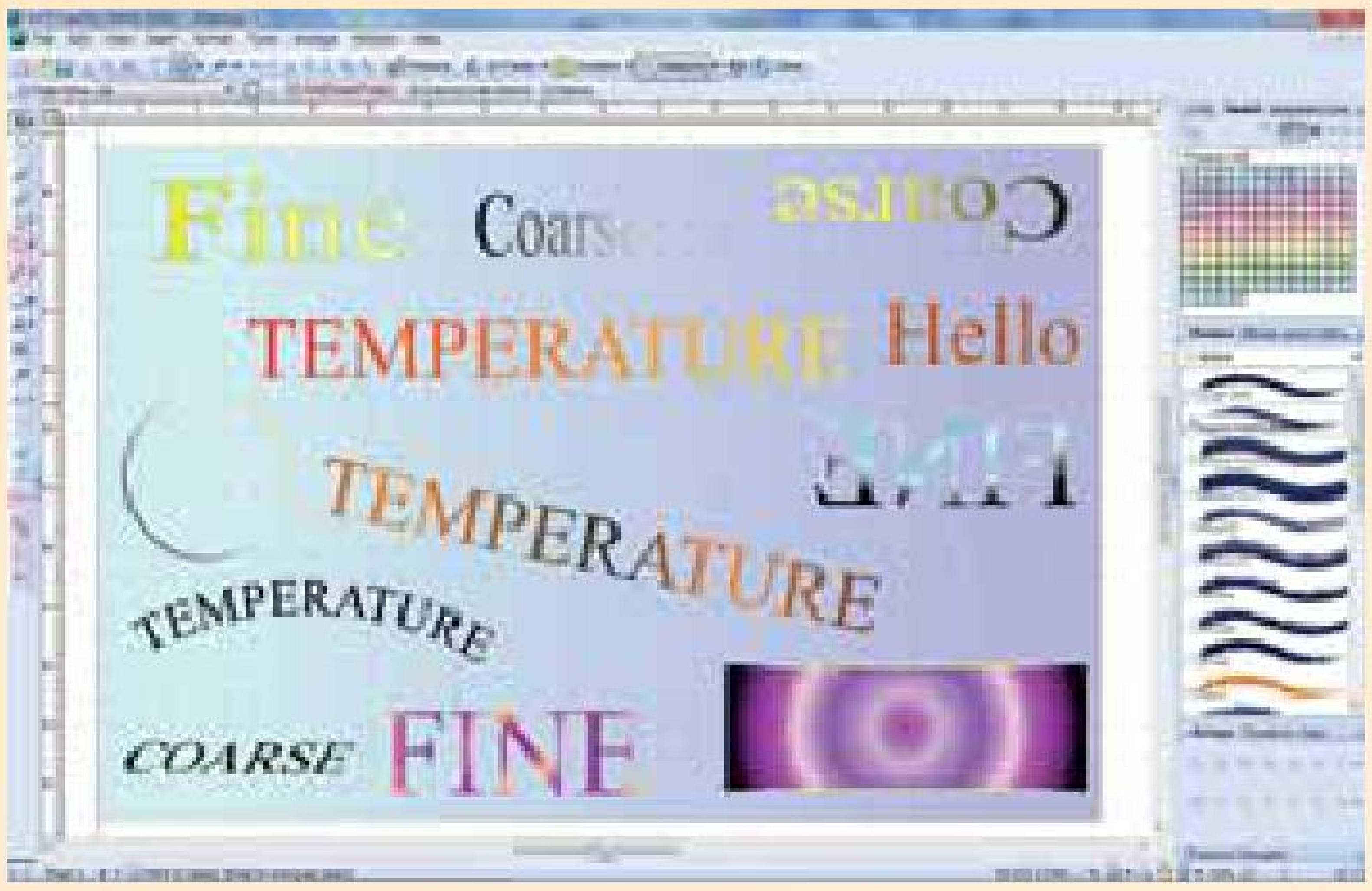


Fig.4. Here a rectangle to represent a front panel has been added over the original demonstration design and given a graduated fill. It has then been stacked behind the other objects, so that they can be brought to the front and made visable again

then the legends are added. There is a potential problem here, you have to make sure that the legends, or any decorative markings added to the panel, appear in front of it rather than behind it and out of sight. By default, newly added items will appear on top of existing objects, so there should be no problem if the outline of the panel is added first. However, the labels, and other embellishments, will disappear from sight if they are put in place first and then the panel is added. Also, care needs to be taken when editing designs, otherwise objects that should appear at the front can disappear into the background.

DrawPlus Starter Edition has facilities for arranging the order of objects, and these are accessed via the 'Arrange' menu. In Fig.4, I have added a rectangle to represent the outline of the front panel, and then applied a graduated fill to it. The 'Send to Back' option was then used to place the rectangle behind everything else. Of course, the same technique can be used to give individual labels any desired background colour. Stacking objects can also be used to provide special effects, with objects partially overlapping other objects. It can be used to provide shadow effects for example.

Even with a fairly simple graphics program, such as DrawPlus Starter Edition, it is possible to produce a dazzling array of effects. As with anything like this, it is a mistake to do things simply because you can. A psychedelic design with all manner of effects might be suitable for some gadgets, but is likely to look ridiculous on a more sober project, such as a piece of test equipment. Try to produce designs that are appropriate for the projects they will be used on, and avoid getting carried away.

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PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

chipKIT Arduino development – Part 2: Altitude Indicator

Last month, we looked at a very simple chipKIT Arduino Sketch, which flashed an LED. Not very useful, given that you can do the same with a couple of transistors. This month, we try something more ambitious – an altitude indicator display, using a GPS module to provide the altitude information and a Nokia mobile phone colour LCD to display it in an interesting way. As the Nokia display has a resolution of 130 × 130 dots, and is fully pixel addressable, we can even add a fancy scrolling graph to show how the altitude is changing over time.

What possible use could this have? It would would make a fun 'vanity' gadget for mountain biking enthusiasts or snowboarders, who would like to know how 'extreme' the terrain is, and perhaps post the data to their Facebook page. Or just use it as an indication of how much exercise you have had. That's our excuse!

We start by describing the devices we are going to attach, and then work through the software development approach within MPIDE – discovering some interesting aspects of the IDE as we go along.

Nokia LCD

The Nokia LCD is from the old 6610 model, which has been around for at least ten years. It's popular enough with hobbyists that a complete 'easy-to-connect-to' module has been created by Olimex (and other companies, but we are using the Olimex version).

These modules include a 3V to 7V DC-to-DC controller to power the LED backlight, and a ten pin 0.1-inch pitch header to ease connection. The whole module runs at 3.3V, so will connect to the chipKIT directly.

There is no datasheet for this LCD, but a large amount of information is available on the Internet explaining how to wire to it, and how to drive it from a variety of microcontrollers. A helpful tutorial from James Lynch (also available on the Internet) reveals the format of the SPI communication link, and this is shown in Fig.1.

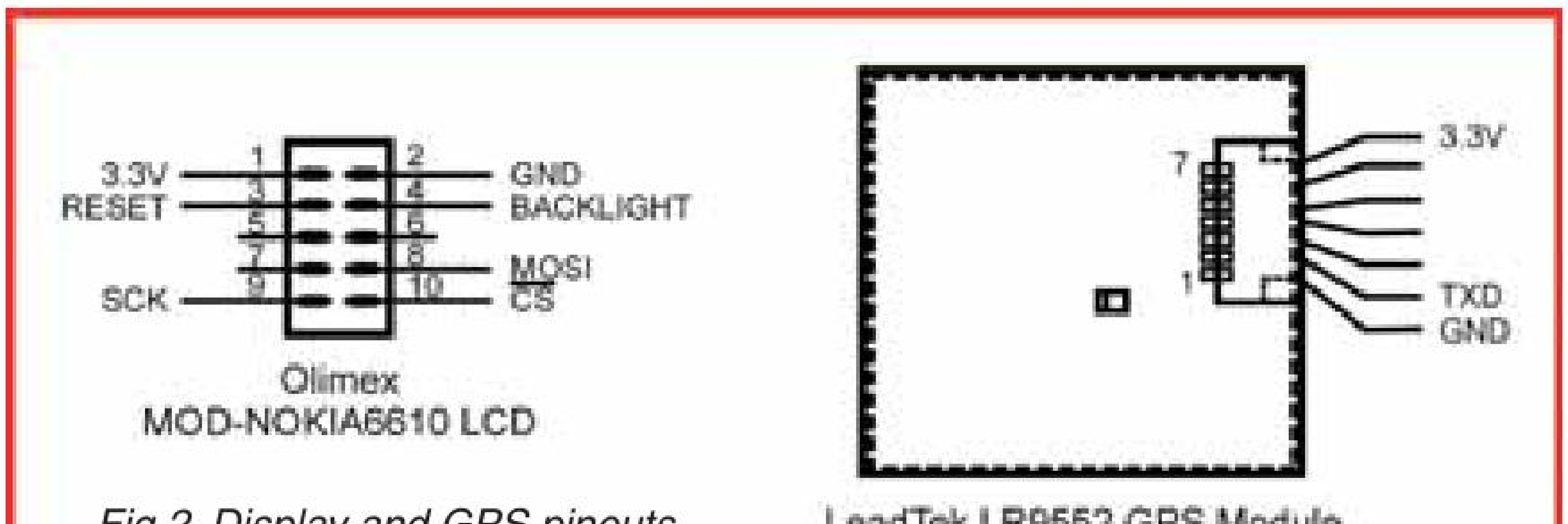


Fig.2. Display and GPS pinouts

It's a 9-bit long data stream, with the first bit indicating whether this is a command or display message, and the remaining 8 bits being the data. The interface can run at up to 6.6MHz, which will allow a full display update rate of 14 times per second – if our SPI library functions will run this fast.

Unfortunately, the chipKIT SPI library that comes with MPIDE only supports 8-bit transmissions, so we will have to write our own SPI interface routine. Fortunately, developing this will be straightforward, as we will see shortly. There is even software freely available on the Internet that we can simply 'port' to the Arduino environment. It took a couple of evenings to find this data on the Internet and cross reference it with other sources to confirm the accuracy, but this research effort was worth it, as it meant we did not need to dig into complex datasheets to work this 'stuff' out ourselves.

The pinout of the LCD connector is detailed on the Olimex website, and can be seen in Fig.2. In addition to the power pins, we need to control the RESET pin, $\overline{CS}$ (the chip select pin), BACKLIGHT ON/OFF, MOSI (the data input pin) and CLK (the SPI clock input). It's unclear what logic levels control the BACKLIGHT and RESET signals, but this becomes clear when reading example software found on the Internet. This is great, as it saves a lot of trial and error.

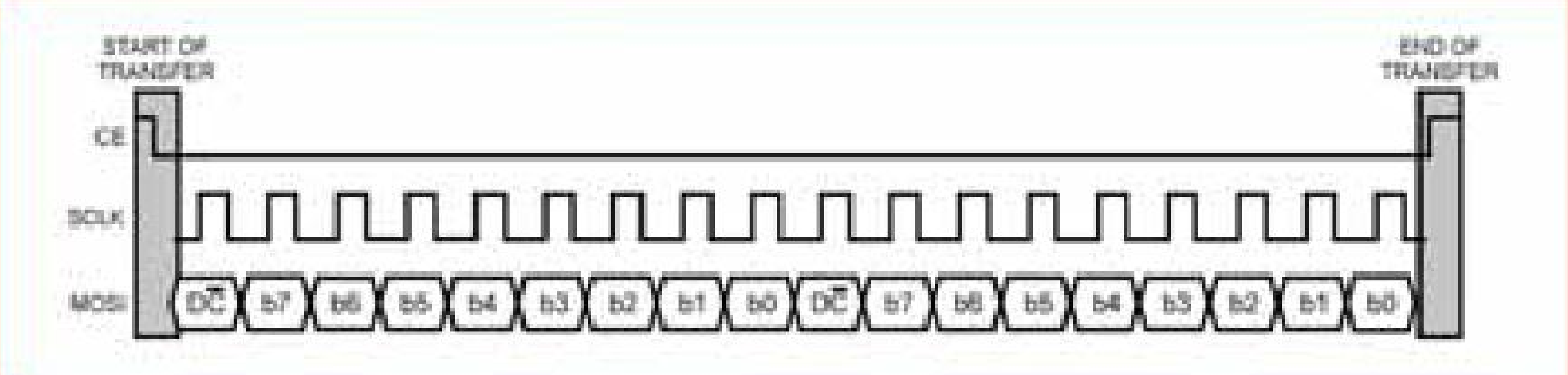


Fig.1. LCD SPI communication

GPS module

The GPS module is a much simpler device to communicate with. This particular module, the LR9552 from LeadTek, has an identical output data format to the one used in our CameraWatch2 project. This is typical of readily available modules on the market today – it operates at 3.3V and generates TTL level RS232 NEMA data at 4800 baud. This too can be connected directly to the chipKIT.

If you plan to build something like this, just look for modules that operate at 3.3V and output TTL level RSR232 ASCII NEMA data and you shouldn't have any problems. The LeadTek module is available from Farnell, part number 1546849.

GPS data is output as a series of lines of text (called 'sentences') in a well defined format. These contain a multitude of data, not all of it of interest to us (today, at least). All we need to know is when the GPS unit has locked onto the satellite network, and what the altitude is. One particular NMEA sentence can tell us this, the sentence that starts with the text **$GPGGA**. The format of this line of text is shown in Fig.3.

While the purpose of many of the fields in this sentence may be unclear, it's fairly safe to say that we need to extract the 'Fix quality' and 'Altitude' fields. The message is in a format that can be easily scanned by a program – once a line starting with the text '$GPGGA' is detected, skip to the sixth and ninth fields and extract the values. Each field is delimited by a comma character, so this should be easy.

GPS modules output these sentences periodically at a rate of once a second, so we will have plenty of time between the messages to process the GPGGA sentence and output the information to the display.

On the button

We are adding a single push 'button' to allow for some future interaction with

```
$GPGGA,123456,5107.018,N,00011.000,W,1,04,0.9,100.9,M,46.9,M,,*34

This breaks down to:

  $GPGGA      Global Positioning System Fix Data
  123456      Fix taken at 12:34:56 UTC
  5107.018,N   Latitude 51 deg 07.018' N
  00011.000,W  Longitude 00 deg 11.000' W
  1           Fix quality:  0 = invalid
                            1 = GPS fix (SPS)
                            2 = DGPS fix
                            3 = PPS fix
                                                  4 = Real Time Kinematic
                                                  5 = Float RTK
                            6 = estimated (dead reckoning) (2.3 feature)
                                                  7 = Manual input mode
                                                  8 = Simulation mode
  04          Number of satellites being tracked
  0.9         Horizontal dilution of position
  100.9,M     Altitude, Meters, above mean sea level
  46.9,M      Height of geoid (mean sea level) above WGS84 ellipsoid
  (empty)     time in seconds since last DGPS update
  (empty)     DGPS station ID number
  *34         the checksum data, always begins with *
```

Fig.3. GPS module data format

the software, probably just clearing the historic display. It has also proved useful during development to simplify debugging and testing different LCD contrast settings.

All parts can be seen in Fig.4. As you can see, the wires have header pins soldered to them and these have then been wrapped in heatshrink cable to protect them from shorting or breaking. Header pins are a useful addition to devices that you use frequently with Arduino modules or breadboards – it not only simplifies plugging the wire in, it also protects the header connectors on the Arduino board from damage.

The two short wires in Fig.4 are the Arduino equivalent of a four-way mains adaptor. We want to connect up three devices, each requiring a ground connection, and two of them to power. The Arduino headers only provide one 3.3V output and two ground connections, so these short cables (which can be hacked together from an IC socket cut in half) provide the extra connections required.

Connecting to the chipKIT

So, we know what we need to hook up – the question now is, to which pins on the processor? This can be one of the most intimidating tasks because the chipKIT has 44 I/O pins that are under our control, many with strange sounding multiple functions. While these can all be configured as digital port pins, many have a secondary function that connect to one or more of the wide range of hardware peripherals within the PIC32, all under software control – somehow!

This is all explained within the processor datasheet. That's all well and good, but we are trying to avoid having to understand the details of the processor, so we will avoid digging into the details of these peripherals for now.

Let's recap on our I/O pin requirements:

Button	Digital input
GPS module	UART input
LCD reset	Digital output
LCD CS	Digital output
LCD SCLK	Digital output
LCD MOSI	Digital output

We know that we should use one of the chipKIT's serial ports for the GPS module. We will avoid the first serial port as this is shared with the bootloader; the reference manual states that there is a second serial port, and its receive signal is on pin 39. So that's one pin sorted out. For the LCD output pins and the button inputs we have a completely free rein, and so have chosen pins at random, selected only on the basis of giving easy physical access. We ended up with the following:

Button	37
GPS module	39
LCD reset	35
LCD light	33
LCD MOSI	31
LCD SCLK	29
LCD CS	27

We will find out shortly whether this is a good choice or not!

So let's hook it all up. It's a good idea to plug in all the wires *before* connecting the board to a power source, such as the USB interface, to avoid damage to the LCD or GPS module. You can see our finished setup in Fig.4

Software

We are working through a series of simple programs leading up to the final design, a summary of which is shown in Fig.5. The full source code files for these various steps can be found on the EPE *website along with the final software.*

Although the circuit we are building is relatively simple, as this is a new hardware platform we creep up on the software slowly to test each connected device. It's a good idea to start with the simplest visible action – flashing the LCD's backlight.

To start with we fired up MPIDE, loaded the Blink example Sketch that we played with last month, and simply modified the pin number we toggle from 13 to 33, matching our LCD's backlight. Connecting the board and the PC together, waiting a few seconds for the USB driver to start, and then clicking the 'Upload' button in MPIDE resulted in a flashing backlight. Great! Simple, but it confirms that the basics are working, and gives a little boost in confidence as we prepare to tackle the more complex features.

We move a little further forward now to test the button. The button is on pin 37, and needs to be initialised as an INPUT within the setup() loop. This introduces a new function call, **digitalRead(pin)**, which will confirm whether a pin (configured as an input) is currently at a HIGH or LOW. We simply wrap the contents of the loop() function in an 'if' statement, like this:

```
void loop() {
  if ( digitalRead(37) == LOW) {
    digitalWrite(33, HIGH);
    delay(1000);
    digitalWrite(33, LOW);
    delay(1000);
  }
}
```

Now, the LCD backlight will only toggle when the button is pressed.

(In theory we should have added a pull-up resistor to the button, in the range of 1KΩ to 47kΩ or so, as the port pins do not have pullups built in. In this case we found the pins typically float high, so it wasn't necessary. Any real design would most definitely require a pull-up resistor).

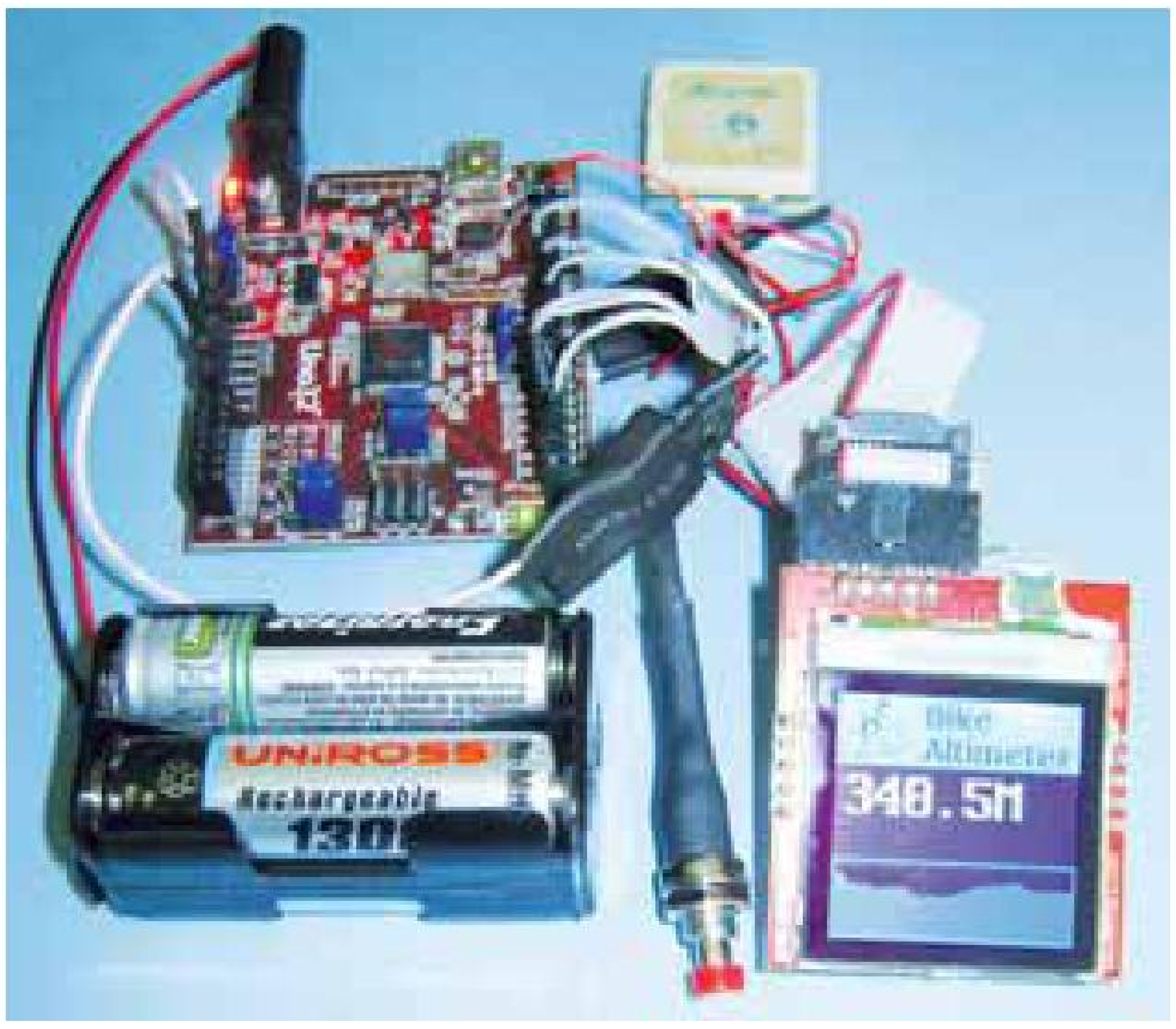
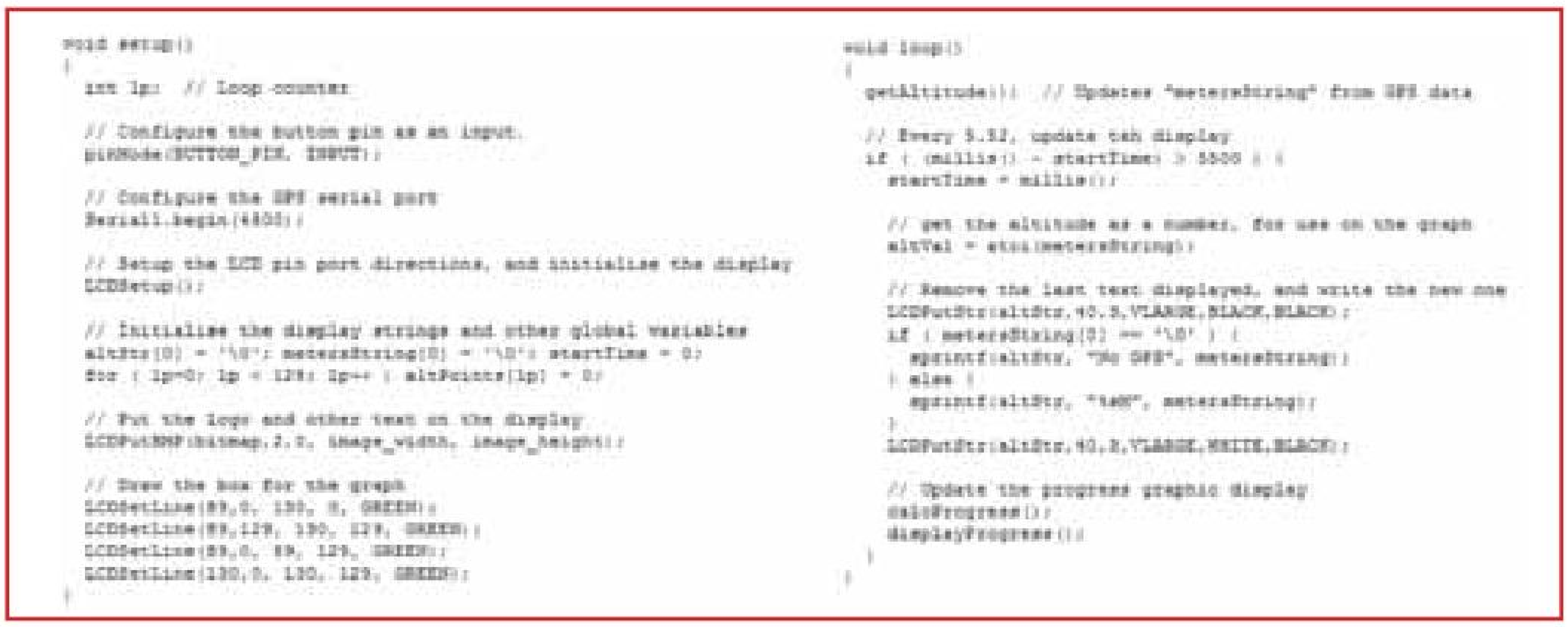


Fig.4. Our devices – display, GPS and a switch



```
void setup()
{
  int lp;  // Loop counter

  // Configure the button pin as an input.
  pinMode(BUTTON_PIN, INPUT);

  // Configure the GPS serial port
  Serial1.begin(4800);

  // Setup the LCD pin port directions, and initialise the display
  LCDSetup();

  // Initialise the display strings and other global variables
  altStr[0] = '\0'; metersString[0] = '\0'; startTime = 0;
  for ( lp=0; lp < 128; lp++ ) altPoints[lp] = 0;

  // Put the logo and other text on the display
  LCDPutBMP(bitmap,2,0, image_width, image_height);

  // Draw the box for the graph
  LCDSetLine(89,0, 130, 0, GREEN);
  LCDSetLine(89,129, 130, 129, GREEN);
  LCDSetLine(89,0, 89, 129, GREEN);
  LCDSetLine(130,0, 130, 129, GREEN);
}
```

```
void loop()
{
  getAltitude();  // Updates "metersString" from GPS data

  // Every 5.5s, update teh display
  if ( (millis() - startTime) > 5500 ) {
    startTime = millis();

    // get the altitude as a number, for use on the graph
    altVal = atoi(metersString);

    // Remove the last text displayed, and write the new one
    LCDPutStr(altStr,40,5,VLARGE,BLACK,BLACK);
    if ( metersString[0] == '\0' ) {
      sprintf(altStr, "No GPS", metersString);
    } else {
      sprintf(altStr, "%sM", metersString);
    }
    LCDPutStr(altStr,40,5,VLARGE,WHITE,BLACK);

    // Update the progress graphic display
    calcProgress();
    displayProgress();
  }
}
```

Fig.5. Final main software loop

SPI Interface

Now things start getting interesting. It's time to develop a bit-bashed SPI interface function, to provide our program with access to the LCD. This approach is normal practice in software development; rather than write one long, complicated and difficult to understand application, we break the problem up into layers, with each layer performing a clear, simple to understand operation. The layers above then become more abstract from the underlying hardware, and the final program will therefore be easier to understand. That's the theory, at least!

The specification for what our SPI function needs to do is provided in Fig.1. As the SPI interface will not be shared with any other parts of the circuit (or *multiplexed*, as it is called), we will set the CS, RESET, SCLK and MOSI ports to outputs in the setup() function, with the CS pin placed in the 'off' state, high, and the SCLK and MOSI pins low.

Each transmission to the LCD consists of one or more bytes, each one preceeded with a single bit indicating whether the byte is a command or data byte. As there could be one or more transmissions in a message to the display, our lowest level function will send a single sequence of nine bits. The caller (the 'next layer up' in our program) can then determine how many times to call it, and control the CS line itself.

This is a very simple routine to write, and can be found in the source code as **void SPISendByte(mode,data)** where **mode** is the value of the first bit, and **data** is the byte to send.

At this point, the single source code file we were building was beginning to get a little disorganised; it would be better to place the low level code and the LCD drawing routines (or 'primitives' as they are called) in their own file. A search on the MPIDE 'Help' system revealed how this is done within the Arduino environment. Simply click the 'Right Arrow' icon on the right-hand side of the MPIDE window, and select 'New Tab'.

We create a file called 'lcd_epson.cpp' and then another called 'lcd_epson.h'. When saved, these were automatically placed in the current project directory, and will be opened whenever you open the main project file. We moved the SPI write routines into lcd_epson.cpp, and references to them and all the shared constants into the header file lcd_epson.h. These files are regular 'C++' language files, and MPIDE will recognise this and compile them as such. To use the routines within our main project file we simply include a reference to the header file, like this:

```
#include "lcd_epson.h"
```

and then call the routines as though they were Arduino library functions. The only difference in fact is that we are storing the source code with our project files, whereas library routines are placed in an MPIDE directory. More on that next month.

It was then a simple task of 'porting' (largely copying) the tutorial display write routines into lcd_epson.cpp. There were two features missing however; the text routines support three font sizes, but we wanted a fourth – a double sized large font. Although this took a fair amount of hacking and two totally different approaches, it wasn't long before a solution was found.

The final feature we wanted was a routine to display colour bitmaps. Sparkfun, a supplier of a similar display, provide a simple .bmp file to 'C' header file generator program, which is freely downloadable from their website. This takes a standard Windows 8-bit colour bitmap image file and generates a header file containing the pixel data as an array of characters. It took less than ten minutes to create the routine to display these, as it is a simple loop and a call to the lower level pixel printing routine. The image drawing routine was not terribly fast, but with the small image we were displaying and the fact that we draw it only once meant it was fast enough.

With the final simple application running the altitude text is updated every 5.5s by erasing the old text and writing the new. The refreshing of the text is visible, due to the fraction of a second that it takes to complete – clearly, it isn't running as fast as we would like. What can we do to improve this?

Using an oscilloscope to view the data signals on the SPI bus, we could see that our 'bit-bashed' interface is running at 450kHz – well below the 6MHz speed supported by the display. The speed could be significantly increased by writing the LCD access routines in C and making use of the SPI hardware peripheral on the processor.

We could also consider putting the display in an 8-bit colour mode rather than 12-bit. This would make the update 30% faster as there are only two bytes to write per pixel rather than three. Using the processor's SPI peripheral hardware could make the display update almost ten times faster, but if the current performance is good enough, there is no need to bother – and thus, you can avoid having to understand the complex details of the processor.

In the end, we used 39KB of the 124KB; not bad considering that 8KB of this is due to font data, bitmap data and startup code. Could we have done better in assembler language? Yes, significantly better. Would there have been a reason to do so? Probably not, unless we were building thousands of these and were looking to save £1 on the cost of the microcontroller IC.

Conclusions so far

It's been fun creating this simple application, which has progressed in a few evenings to the point where we could put it in a box and start using it. (Actually, we have, and will discuss this next month.) The chipKIT board has plenty of free memory, which means we could add many extra features, such as a download facility to save the graph to a PC.

It's become apparent that MPIDE is quite a limited development environment. When editing, for example, you cannot close one or more of the files in your project – it's all open, or none at all. This was a problem when updating the bitmap header file, as you had to close the whole IDE down to be able to overwrite it. Twenty years ago it could have been considered a great innovation, but in today's world it is a pain switching from our more usual development environments such as MPLAB, Eclipse or even Crimson editor.

The 'Arduino language' is really nothing more than the C++ programming language. In the end, we gave up pretending it was anything else. Nothing wrong with that; Arduino provides a simple introduction to programming, but does not limit you to exploring the full capabilities of the C++ language as your confidence grows, and it was a great help to be able to code in the native language when necessary.

Next month, we discard the GPS and LCD in favour of a handful of resistors to test the chipKit's PIC32 processor to its limits.

References

bitmap to .h utility: http://www.zipfelmaus.com/nokia6100lcd_en/

James Lynch's tutorial: http://www.sparkfun.com/tutorial/Nokia 6100 LCD Display Driver.pdf

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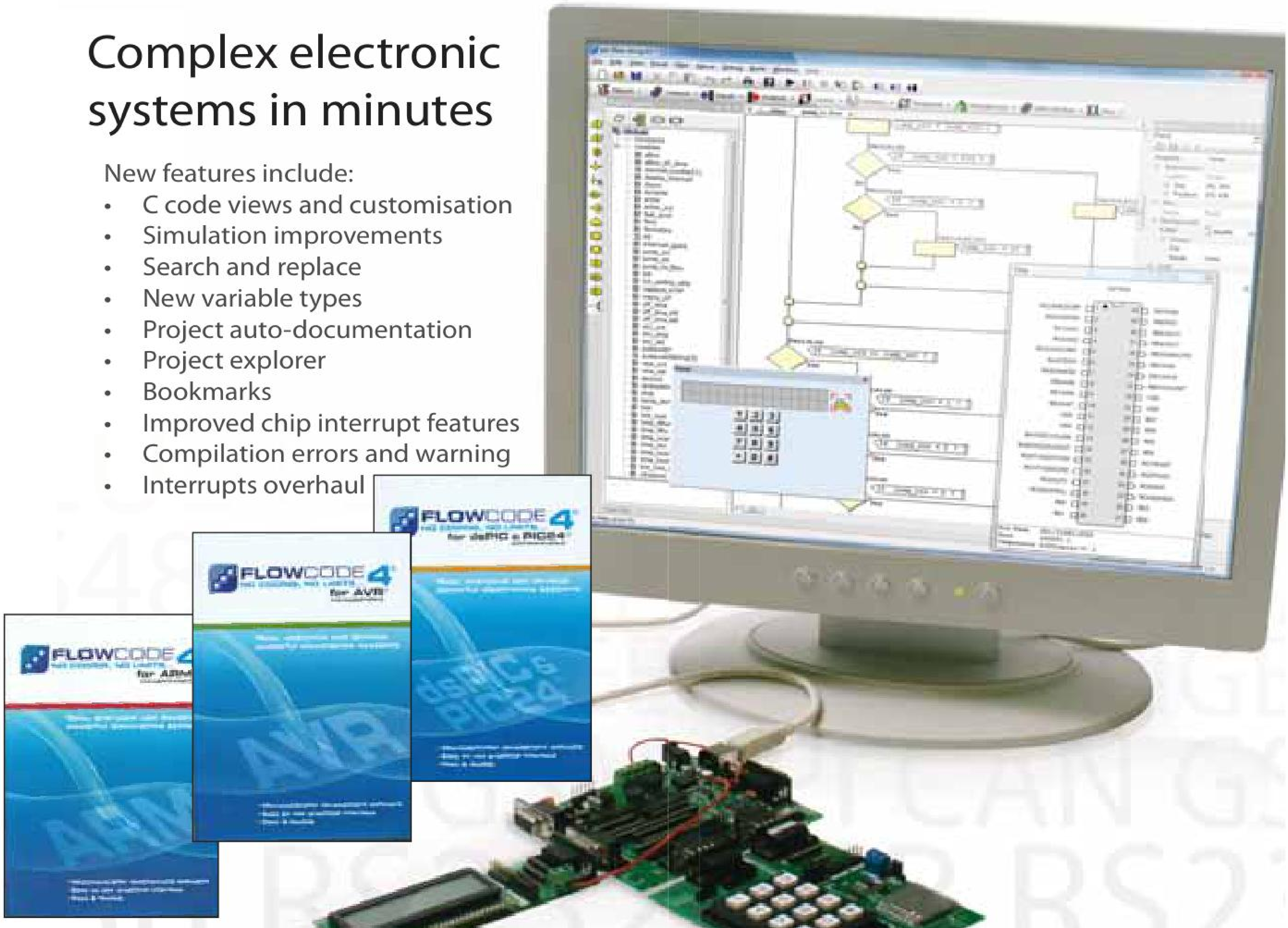

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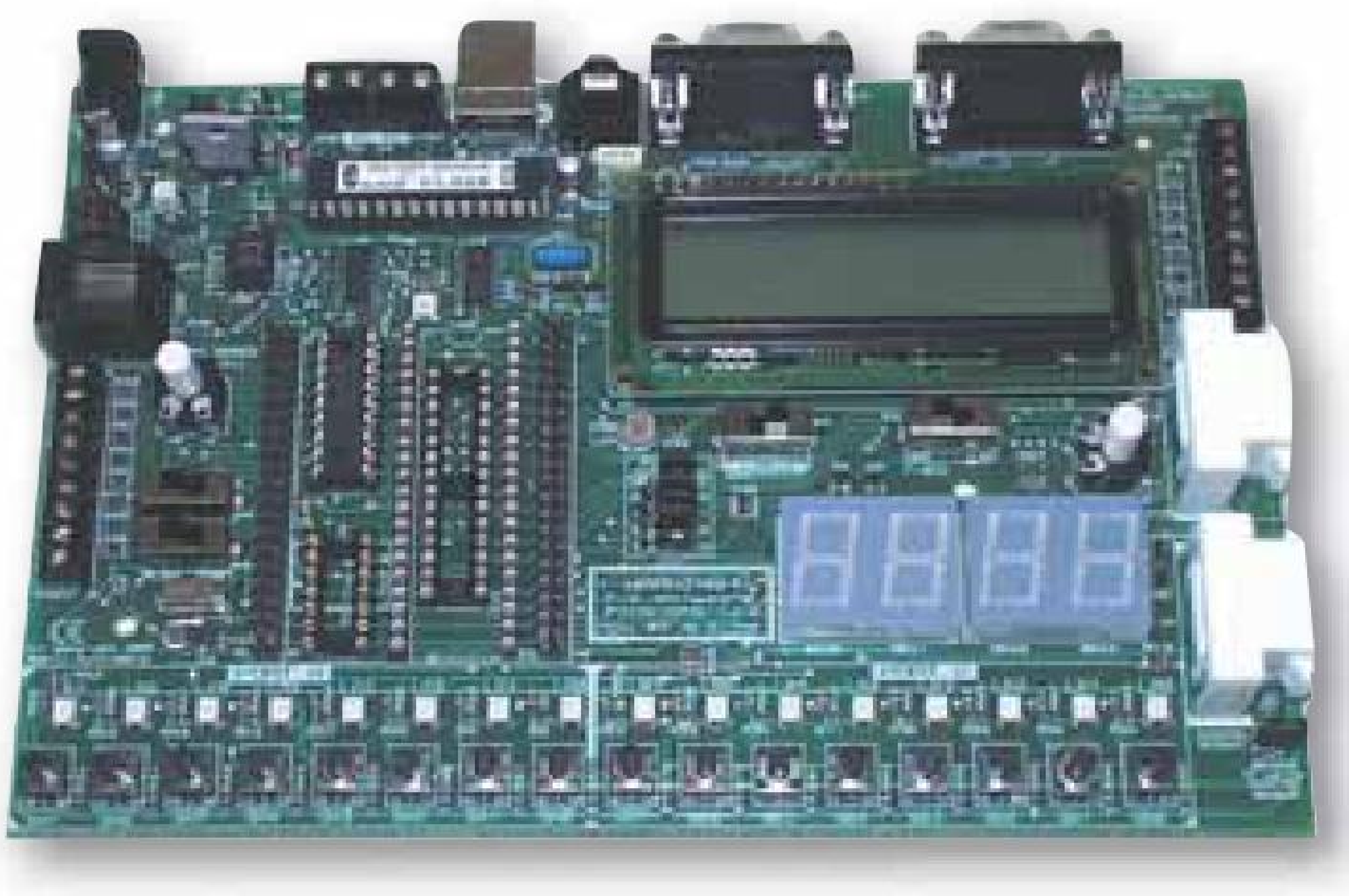

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SOFTWARE

ASSEMBLY FOR PICmicro V4

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

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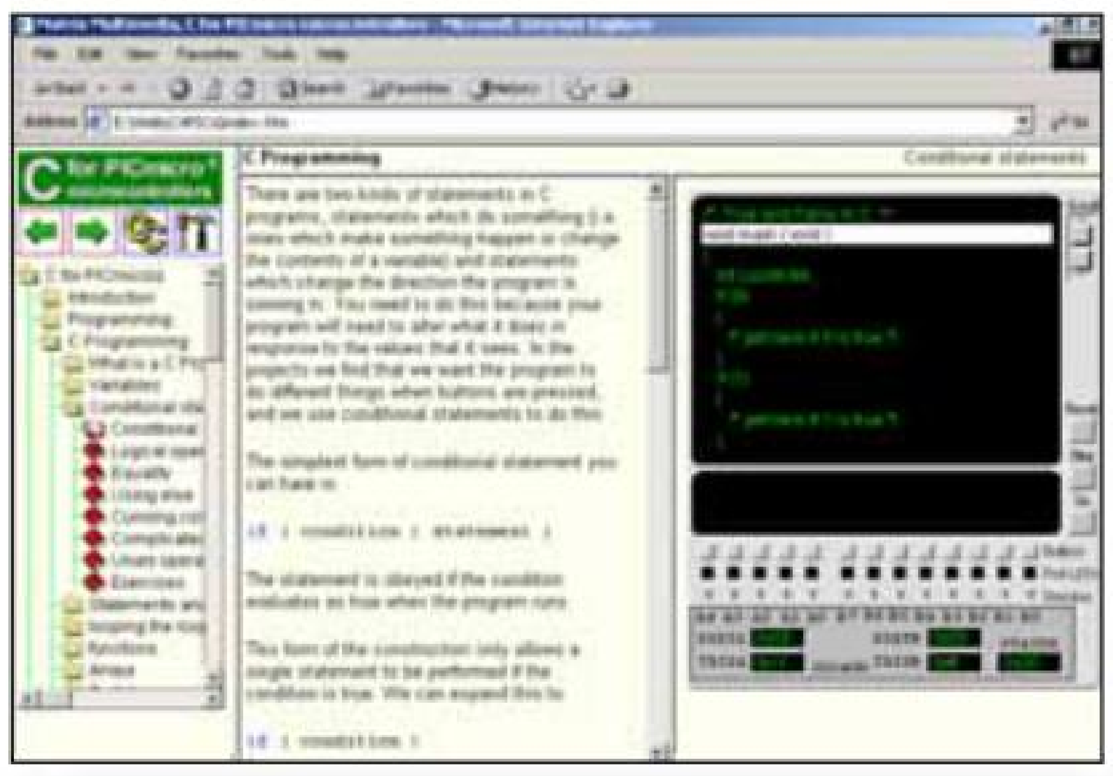

Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

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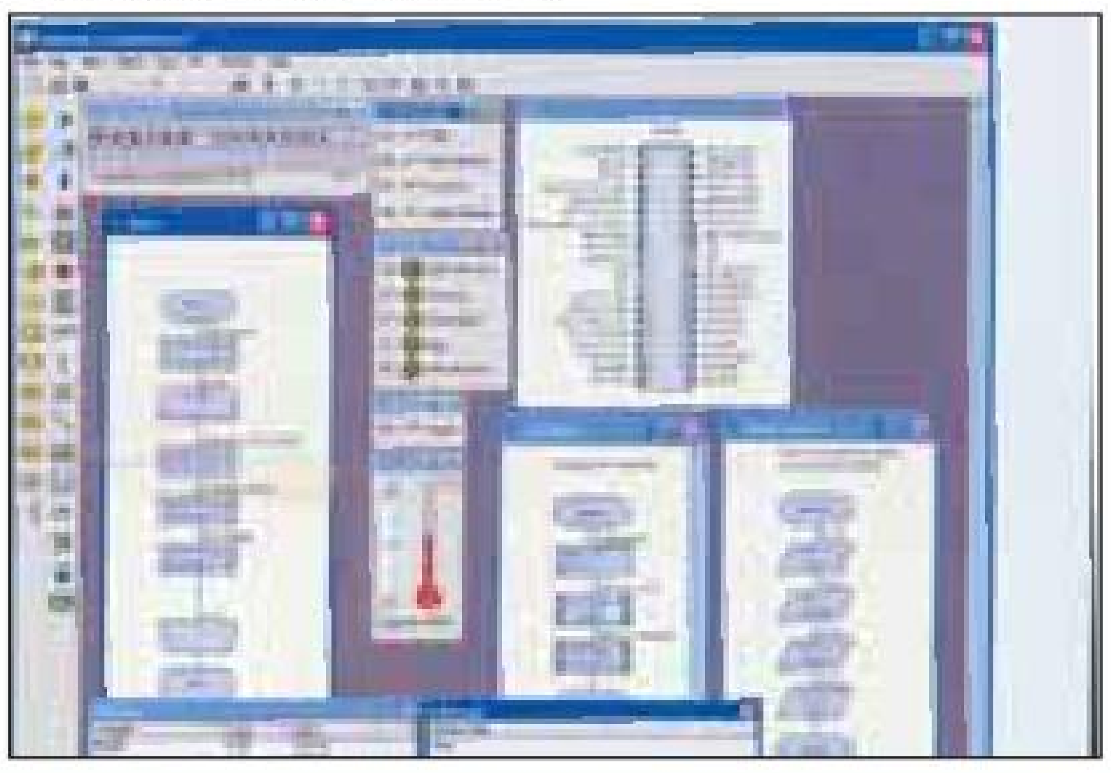

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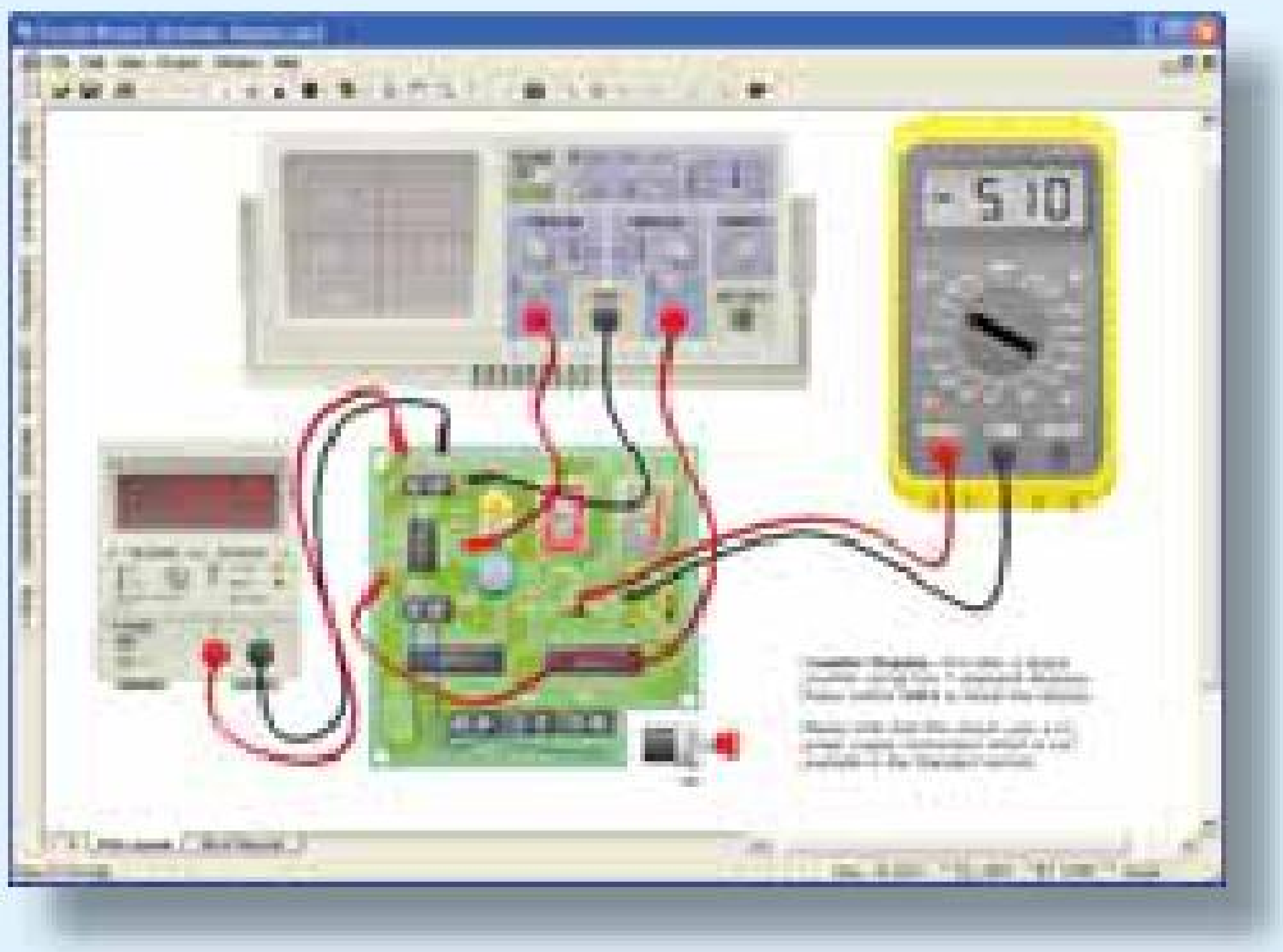

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

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- EPE PIC Tutorial V2 complete series of articles plus demonstration software, John Becker, April, May, June '03
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READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

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All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

WIB champion

Dear editor
I would like to start by thanking you for printing the *Webserver In a Box (WIB)* design in your December 2011 issue. The article got me thinking about my needs for a remotely operated data logger system, basing it around the WIB design. Its powerful dsPIC processor and SD card storage make it the ideal building block.

The *EPE* design is very good, but could be easily enhanced. I have a 12V power supply, but using a linear regulator to create 3.3V from 12V is very inefficient. A commercially available step-down converter from Farnell could reduce power loss by 1.5W to 2W. Alternatively, changing the LM317 to an LD33V low drop-out (LDO) regulator would easily facilitate operation from a 5V supply. As these changes could not be easily incorporated into the existing PCB, I have re-tracked it. The design will be made available online.

As a regular user of the *EPE Chat Zone* (**www.chatzones.co.uk**) I was aware, at an early stage, of the unavailability of the original SD card connector. Some recommended replacements were suggested, which I duly purchased and added to my custom PCB. For ease of use, a PIC in-circuit serial programming (ICSP) connector was also added – see Ian's link for photo. The updated design has now been thoroughly tested and has proven very reliable.

EPE's Chat Zone has been a wonderful resource for discussing design issues, adapting the software for the larger 128K dsPIC part and general queries. I strongly advise readers to visit the *Zone* for help with the design – it has certainly been popular.

I have adapted the software source code supplied with the design, and created a new software release that removes the need for the MAC EEPROM, but supports the ICMP protocol and hence ping messages. See the *Chat Zone* for further details.

My future plans for this design are to adapt it to interface to a couple of sensors and act as a remotely accessible data logger, with a future upgrade using a Microchip Wi-Fi module. The hardware design is not too tricky, but the software will be an interesting challenge.

I have posted a Wiki that describes these changes in much greater detail, see: **http://wibwiki.wikispaces.com**.

Ian Stedman, by email

Matt Pulzer replies:

Most impressive work Ian; if there is one thing we like more than a good project, it's seeing readers improve it. WIB *has been one of the most popular projects of recent years, and I would like to echo Ian's advice for readers/constructors to go to the Chat Zone if problems have been encountered.*

Pre-programmed chips

Dear editor
Is there a replacement supplier for pre-programmed chips now that Magenta has stopped offering this service ?

I am sure programming them myself is not very difficult, but I don't want to have to invest in the different programmers that I assume are required for the many projects you now publish that are Microchip based. No doubt there is an article on how this is done, but I don't recall seeing one recently.

Malcolm Read, by email

Matthew Pulzer replies:

I am not aware of a company that offers one-off programming of chips – perhaps a reader knows otherwise? However, as you will see from February's article on PIC programming, much of the programming for projects in EPE *is covered by one, easy-to-use and cheap piece of equipment – the excellent PICkit 3 from Microchip.*

Furthermore, the regular PIC n' Mix *articles by Mike Hibbett are an excellent introduction to this fascinating and flexible technology. I appreciate that this does not directly answer your question, but you really can go a long way with just the PICkit 3, especially with most 'smart'* EPE *projects*

The secret's in the code

Dear editor
I have wanted to write to you for some time now, but had not been able to get around to it. If you think you are busy now, just wait until you retire!

About two months ago, my wife and I went grocery shopping and while I was busy putting my debit card away I heard a 'scream', followed by expletives coming from the kitchen. My wife is a very calm quiet person, and hardly ever gets into hysterics over a till receipt – 'What's the matter?' I asked. 'They've done it again', she said. 'Who? done what?' 'Those **!$@*s have charged me three times over for the bread.'

This was the same day I noticed an inch and a half square on the front page of the newspaper, with strange symbols. I thought of Dan Brown's novel – *The Lost Symbol* – but what could it mean?! Later, I picked up my copy of *EPE*, turned to my favourite pages, *Net Work*, and there it was again, the same type of symbol!

The electronics industry has never been backward in coming forward to tell us what we 'must' have, but sometimes they miss the real money maker by packing in too much of what we don't really need.

QR codes, it seems, could be useful, but for me at this time, all I want is a simple bar code reader. There was a supermarket chain, which had a branch near where I used to live (I think they went belly up) which came up with the idea of letting registered customers scan items as they go around the store, then just paying at a special checkout with only one in ten trolleys actually checked. For this, the store provided a small portable scanner.

I have always wanted one of those scanners, and I suspect there are thousands of people who feel the same way, because every time I go into a store there is always an item that is not price marked and quite often wrongly priced. Just think how confident my other half would be if she carried a barcode scanner while shopping. Is there a mobile phone size one on the market?

Phil Foster, by email

Alan Winstanley replies:

Thanks for your email and for your kind comments about my Net Work *column. I enjoyed reading your mail.*

I have been heavily involved with product and packaging design, and I worked closely with barcode systems and artwork as part of my job. The point is, product barcodes are meaningless unless they reference a database. A scanner merely captures a product's unique digital data and 'looks it up' on a database of stock levels and prices.

EPE *aficionados might seek out* EPE *August 1993 issue for my article on* Those Amazing Barcodes.

To answer your question, a typical EAN8 or EAN13 barcode merely represents the barcode's country of origin, the manufacturer's unique ID and item number, and a check digit. It contains no pricing data directly. So, in order to scan an item at your local store to verify the retail price, you'd have to access a look-up database and obviously, the same item might cost something else at a different store.

Barcode reader apps are readily available for mobile phones (eg, ZXing for Android), relying on their built-in camera rather than a laser diode. Have a look at **www.mobiletag.com** *for starters. Price-comparison barcode reader apps seem to be emerging, but it is early days, and I have not tested them. I can imagine there will be many an in-store rumpus when they become commonplace in the next few years.*

Alan Winstanley, EPE online editor

Readers can contact Alan by email at: alan@epemag.demon.co.uk

Mac vs Windows OS security

Dear editor
My son, who is a software developer, persuaded me to buy an Apple Mac instead of a Windows-based computer. He said that I do not need any security software for it as there are no viruses for a Mac.

Should I buy some security software and which software would you recommend?

Please keep up the good work, I enjoy your articles every month.

Jim Bennett, by email

Alan Winstanley replies:

Thank you for your email and for your kind comments.

Mac owners often say that their systems are immune from viruses or worms, though I doubt if anyone (including Apple themselves) will ever give a money-back guarantee that their systems cannot be attacked in the future by, for example, a malicious website hosting trojans; subjected to malicious scareware or viruses introduced by peripheral hardware such as a USB drive, key logger; or infection through eavesdropping via VoIP or Bluetooth.

Many forms of IT hardware, including ATMs and credit card machines have been hacked in ways that are unimaginable, and recently an engineer was intercepted in the UK carrying Bluetooth-based hardware capable of capturing PIN numbers. I acknowledge that Windows users have a hard time because the sheer size of the Windows user base offers a happy hunting ground that can be exploited by malicious hackers and virus writers around the world.

Personally, I would never take anything for granted, nor would I fully believe any cast-iron assurances about security. In my opinion, it's foolhardy to assume total immunity from an attack. To help you decide, the business-service security firm Sophos published a History of Apple Mac Viruses 1982-2010 *at:* **http://tinyurl.com/27ujnhy**

I'm afraid I can give no personal recommendations for Mac anti-virus software. Norton AntiVirus 12 for Mac costs £39.99 per year per machine (see **http://tinyurl.com/653ake5***), and I believe any such product will be better than nothing at all. Mobile phone users are fast becoming susceptible to similar issues. I'm afraid it's all part of the hidden cost of ownership of an IT system today.*

Matthew Pulzer also replies

The answer to this is partly historical, partly technical and partly 'demographic'. Mac OS X is based on UNIX, which has always had some security built into it, and it was inherently more secure than earlier versions of Windows. This helped to build the 'more secure' reputation, but is probably an obsolete reason now.

Second, since Apple 'make everything' from the ground up, ie both hardware and software, they are in a better position to build-in security to their systems. It also means there aren't hundreds of different Apple computer varieties, opening up vulnerabilities as designers try to accommodate a wide specification of 'what a PC is'. Apple has also been very good at supplying OS upgrades over the web with extremely straightforward installation, which encourages users to keep up to date, thereby helping to suppress whatever malware is out there.

Third, Alan is quite correct to point out that the vastly larger Windows user base means that it is a much more attractive target for virus writers.

Last, some anecdotal comments. I used to be a Windows user, up to XP; after that, I switched to Mac OS. My personal experience has been that with Windows I had a great deal of problems with viruses (and also anti-virus software). However, in the near-ten years of using a Mac I have never had a virus problem – not once.

I should point out that as a magazine editor, I receive a great deal of emails with attachments and I am a pretty heavy user of the Internet – I should be a prime target for problems. For nine of those ten Mac years I had no anti-virus software at all. This wasn't just arrogant 'Apple-fan bravura', but based on good advice.

A cousin of mine runs the computer system for a Cambridge-based commercial physics research company. He is responsible for servers, personal computers, and a great deal of valuable, commercially-sensitive data. His system was all Apple based, and up until roughly this time last year, his experience-based advice to me, as a Mac user, was to not bother with any anti-virus software.

His view was that the hassle of installing and maintaining it was simply not worth the very small risk of the viral risks to Macs. Now, however, he does feel that while the risk is still small, it is not trivial, and he recommends the free Mac anti-virus software from respected supplier Sophos, available at: **http://www.sophos.com/en-us/products/free-tools/sophos-antivirus-for-mac-home-edition.aspx**.

I'll end this point with a reminder that my experience is purely personal, and I really don't want to engage in system wars. No computer or computer-based system is immune to attack, but for a variety of reasons I do believe Macs are somewhat safer. That said, I do now use and recommend the Sophos product mentioned above

Bespoke boxes and other hardware

Dear editor
One possible solution, around Nigel Fraser's problem (Thinking outside the box, Readout, Oct 2011) is the use of 3D printing for short-runs or demo boxes. Boxes can be 'printed' in plastic, glass or metal (including stainless-steel), depending on the company's equipment. A company that does this kind of work is: www.shapeways.com, though there are others around, and closer to home.

You need to generate CAD files for the case, but you would get exactly what you draw.

Liam Collins, by email

Matthew Pulzer replies:

Thank you Liam, last time I checked the Shapeways website they had a nice little case for the Raspberry Pi on the home page, so you are spot on with your suggestion

Pico IU Prize

Dear editor
At first I couldn't understand why the postman had delivered an oscilloscope that I hadn't ordered. But then I read your letter.

I built my first oscilloscope when I was still a student. It used a CRT from a WW2 aircraft radar. The circuitry of the Japanese double beam scope I am using at present is essentially the same as my original – except that transistors have replaced valves. But the Pico PC-based scope is, of course, quite different, I am looking forward to getting to grips with it and making good use of it.

Thank you for a delightful and unexpected award; and please pass my thanks to Pico for their generosity

Murray Ward, Godalming

Matthew Pulzer replies:

Thanks for thanks Murray! Readers of my September 2011 editorial will remember that Murray won a superb PicoScope 3206 Digital Storage Oscilloscope worth £799 for his outstanding Ingenuity Unlimited *submission* – Regulating grandfather by radio. *He managed to combine a radio time signal, a cheap radio clock, analogue electronics and electromechanical components to regulate the pendulum of his 18th century grandfather clock (without altering the clock's precious 'works'). He is a worthy winner, well done.*

If you have a great idea, or have built an unusual or clever circuit or project, we'd love to hear about it. We publish and pay for the best; plus, you get a chance to win a fabulous prize.

More on SI units

Dear editor
In the April 2012 issue (p.66) I read Stef Niewiadomski's letter about SI units with a big smile on my face. You see, I created a chart that goes beyond the usual basic information that I believe will help 'newbies' to see the difference between SI and US notation.

Please have a look at my website: **http://elecurls.tripod.com/Euro_vs_USA.htm**

Keep up the great work!

Ted Mieske, California, USA

Matthew Pulzer replies:

Great work Ted, I particularly enjoyed the translation from English to American!

Rage against the machine!

Dear editor
I think the news item on Raspberry Pi in the March issue had the wrong address for the beginners guide to Raspberry Pi – there should not be a space between 'rasp' and 'berry'.

I do wonder what idiot said that computers can be a great help in life, because I seem to spend most of my time fighting the things.

At the moment, they are talking about illegal information gathering, but anybody purchasing the Dragon dictation program is required to authenticate it, and after the process is complete, you get a ten-page questionnaire that asks you almost everything about your habits (almost down to your size in hats) which I refused to answer.

They then offer you a service for improving your accuracy, which requires you to send every scrap of dictation to them to play around with.

Now, despite an anticipated law demanding that suppliers ask for permission to insert cookies on your computer it still seems to happen and one of the worst offenders is the BBC.

Despite having all these anti-virus programs, I still frequently get problems. However, a neighbour of mine has never had any problems, despite being online for two years and she doesn't have an anti-virus program. It does make you wonder if it's all scareware.

I read once that an unprotected computer will get infected within five seconds, and yet when you buy a computer from new and manage to download your Internet provider's software you have been online for probably 30 minutes with no problems.

All very curious.

GS Chatley, by email

Alan Winstanley replies:

*Thanks for the email. Yes there was an unfortunate space in the Raspberry Pi address. (*My fault! – Ed*)*

I covered the EU cookie law problem in the April issue of Net Work. *Cookies bring some user benefits, but there are privacy implications too: they can help to 'personalise' web page adverts, as they can focus more on your own surfing history rather than the context of a website that displays it. Some people will find this intrusive and unsettling. It's to be hoped that a future web browser upgrade will allow suitable end-user control over cookies.*

Regarding anti-virus software, your neighbour's system could be infected without his or her knowledge, including: a spamming virus sending out junk, or being controlled as part of a botnet's distributed denial of service (DDoS) attack against another website; or keyloggers recording their online transactions in the background (eg, credit card capture or login data).

Using social engineering techniques, online fraudsters try to silently defraud their victims without mercy, and I believe that anti-virus protection and regular updates are absolutely critical. You would be doing us all a favour by pointing your neighbour immediately to AVG Free Edition or Microsoft Security Essentials free anti-virus (and also maybe MalwareBytes' anti-malware and Spybot Search and Destroy). I'm afraid there's no reason at all not to be covered, if only to protect everyone else! Thank you for your continued interest.

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NET WORK

by Alan Winstanley

On guard!

WELCOME to this month's *Net Work*, the column written to help readers get more from the Internet. *EPE* readers generally have a large advantage over many Internet users in that they are technically-orientated, but I am constantly appalled by the cases I come across of ordinary non-technical users falling for the latest scams.

I'll start this month's column with a timely warning about phoney and unscrupulous IT support scammers that cold-call Internet users to advise 'customers' that they have a problem with their system. In a typical scenario, Internet users receive an unsolicited phone call from someone with a British-sounding name accompanied by a thick foreign accent. The scammers claim that they work for Microsoft or BT, for example, and that there is a technical problem on the user's computer. After running some 'tests', they will then offer to fix it. In effect, what happens is that the scammers trick their way into setting up a remote networking session: one victim told me a few days ago how he was totally amazed by the fact that his mouse pointer was moving around on-screen without any input from him: he had never seen anything like it.

It then appears that a rogue 'scareware' program is installed and run on the local system, which appears to scan the computer's registry. The victim looks on wide-eyed while a string of so-called 'errors' is displayed on his screen. Of course, there will always be Windows registry 'errors', which are frequently benign in nature, such as legacy file associations from uninstalled programs, or a missing document's pathname, but the errors look very worrying to the uninitiated and the helpless victim becomes a prime target to be ripped off without mercy.

What next!

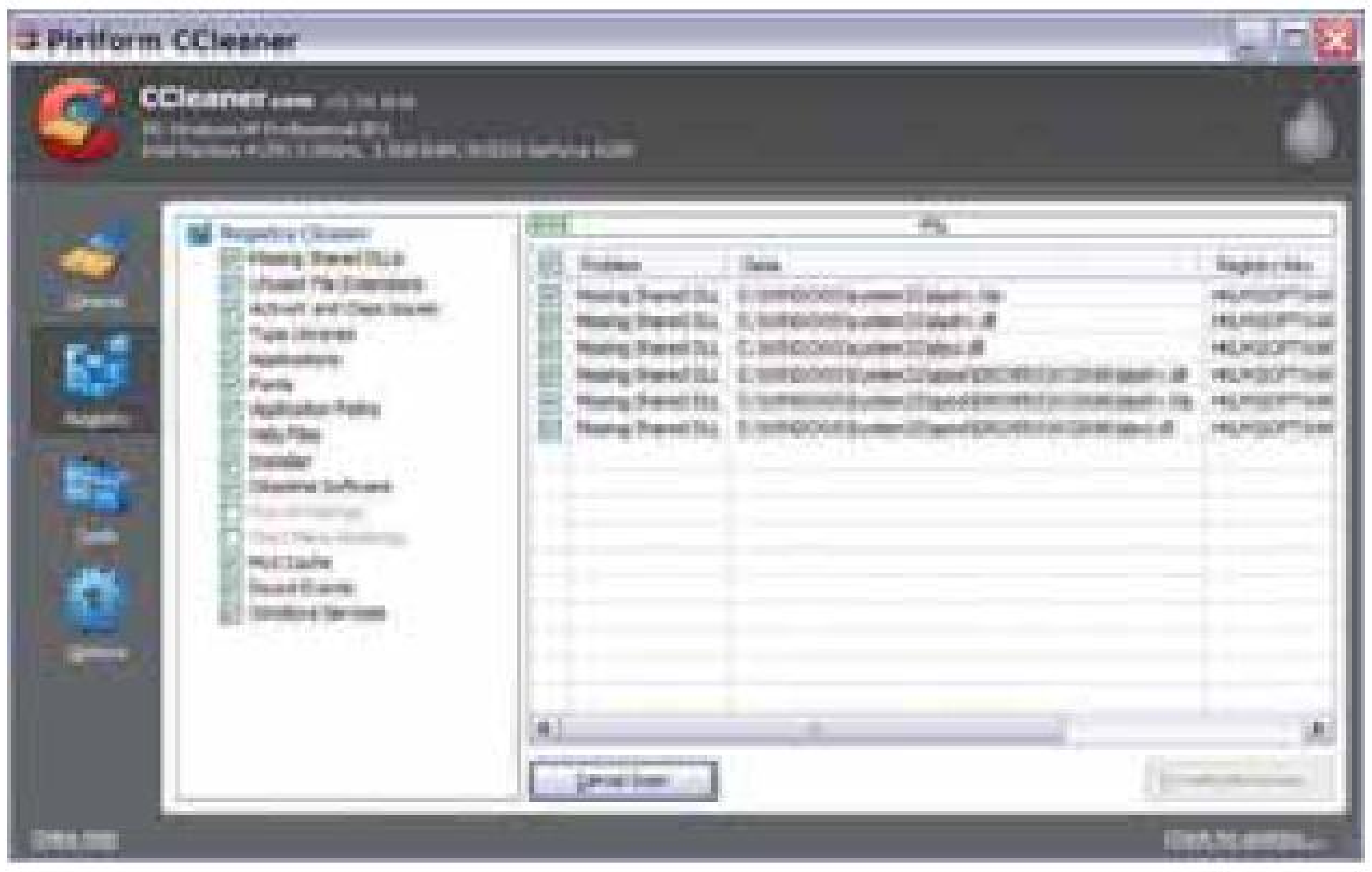
EPE readers can guess what happens next: the scammers play upon these fears and they fret people into 'unlocking' what is a worthless piece of software. All it takes is a credit card number and then victims can be stung for hundreds of pounds. My 'relieved' victim reported that, after a short time, their laptop started to lock up and not even their local IT repair shop could fix it despite several visits to the store.

There is also evidence that such details get sold on to other scammers, rather like being placed on a 'sucker's list'. The same person claims to have received several such calls from different companies after falling for the trick once already, but he learned an expensive lesson.

I can well understand how inexperienced or elderly Internet users could fall for this shameful con-trick, but the scam gets uncomfortably close to home when friends or family are involved. *EPE* readers can help to counter this heartless scam by educating vulnerable users not to succumb to such an exploit. There is no such thing as unsolicited telephone support, and never allow an untrusted third party to attempt to connect to your system remotely. No-one will ever cold call you claiming that your system has an error, and credit card details should never be given out to them.

So-called 'scareware' programs often surface when I'm scouting around on the web. Many *EPE* readers will have seen phoney pop-ups appear that warn of errors on their system, and frequently they will be offered a free 'scan'. To fix the problem, of course, requires you to purchase a program. It's a lucrative business and in 2010 a pair of US fraudsters were prosecuted for running an $8 million scareware scam that duped millions of users; see: **www.ftc.gov/opa/2011/01/winsoftware.shtm**

It's worth remembering that a free, high quality registry tool called CCleaner is available from the heroes at Piriform (**www.piriform.com**). This is probably the only registry tool that most Windows users will ever need. CCleaner includes a great uninstaller tool – how many times have you visited the Windows control panel to remove a program, only to suffer a lengthy delay while Windows lists all the programs available for uninstalling? CCleaner lists all such programs instantly, ready for removal. It is a much faster way of removing programs, especially on older machines.



Piriform's CCleaner is an excellent free registry repair tool and uninstaller

I have discussed registry tools in the past, and it remains the case that there are countless semi-worthless software downloads around. The download link itself can be obfuscated, and I also hate visiting a website *en route* to a specific download, when I am confronted with a large 'Download Here' link instead, only to find that I missed my intended target and clicked-through an advertiser's link that has just earned somebody a few cents.

Life's a lottery

Other forms of online scams continue unabated. The writer's email address is still bombarded with phoney lottery ticket prizes or fraudulent phishing emails; as I write this article I learn that I have just won €500,000 in the Euro Million Online Raffle and £½ million in the London Olympic 2012 Games Lottery as well. It seems that some major UK banks are singled out for special treatment: numerous phishing emails posing as Santander and Halifax arrive constantly. Almost every email starts with 'Dear Customer', which is an immediate giveaway, though some try to appear more authentic by including your email address in the text instead.

Countless phishing mails still arrive with an elaborate cover story promising instant riches. Some of them stoop very low, spinning the most appalling story of terminal illness or suffering. Scam emails usually end by asking for your details, date of birth and phone number. The catch is, of course, that having ensnared you, they will start to milk you for up-front fees. This is 'Advance Fee' or '419' fraud in full swing, and it is so widely publicised that one would think they had run out of steam by now, but a fool is born every minute and if only one or two take the bait – it is always fuelled by personal greed – then rich pickings can still be had by these fraudsters. Advance Fee fraud is not unique to the Internet though, as the Serious Fraud Office described in the £4 million Gresham Ltd case. See **http://tinyurl.com/7o85xnv**

Bogus websites offering cheap finance are also widespread. This is a particularly cruel scam because it targets vulnerable, undiscerning people who genuinely need financial help. The websites ask for personal details and a phone number to verify their identity. A British TV crew made a phoney application online and received a phone call immediately, confirming they were eligible for a cheap loan; a vulnerable couple in Coventry were tricked by the same foreign callers into paying £450 in advance fees.

Other scams that are still prevalent include 'Personal Shopper' fraud, asking you to purchase goods with your credit card for shipping to other countries. Any payments you receive eventually 'bounce'. Money laundering con-tricks recruit victims by email to act as a 'Payment Processing Agent'. You may receive (stolen) monies that you forward to the crooks, in return for keeping 10% as commission. The stolen money is then clawed back, so you lose the cash that you forwarded to the crooks. To make matters worse, in Britain, the money-launderers are also held criminally liable, no matter how gullible or naive they are.

There is probably no finer online resource in the world to explain how these villains work than Bob Bear (**www.bobbear.co.uk**) where an endless list of current and archived frauds is listed. The website should be compulsory reading to help inexperienced users recognise common types of online fraud.

Once again, tech-savvy *EPE* readers can do their bit by helping to ensure that friends and family are alerted to the kind of social engineering and unscrupulous trickery that is all too prevalent on the Internet these days.

In summary

- Try to maintain up to date anti-virus software to protect your system against keylogging attacks, banking Trojans or infected websites. The latest banking Trojans are extremely sophisticated and AV software is the best protection that you have. It also helps prevent your machine being taken over by botnets. Some banks (eg, HSBC) provide Rapport software free to authenticate a banking website's address.
- Personal details posted online can help ID thieves to build a more realistic profile of you. Consider whether you are posting too much information in your Facebook profile.
- Using strong passwords with some non-alphanumeric characters makes it much harder for hackers to guess your logins. They will hopefully give up and try easier pickings elsewhere.
- Malwarebytes Anti-Malware software from **malwarebytes.org (only)** and Spybot Search and Destroy from **www.safer-networking.org (only)** are highly recommended. Scan your system periodically and beware of sound-alike imitations.
- Emails that start 'Dear Customer', or which do not address you by name, can be dismissed straight away. While it's tempting to respond with a pithy comment, never reply nor arrange to meet anyone: some criminal gangs operate from abroad (eg, Rotterdam) and can visit a London hotel and return home in a day.
- Never buy online from an unknown source if payment by Western Union is requested. It helps to enrol debit and credit cards in authentication systems, including Verified by Visa and Mastercard SecureCode.

On location

Last month, I mentioned the MaxMind GeoIP website (**www.maxmind.com**) which claims to help pinpoint the physical address of a user based on their IP address. Data can then be used for marketing or anti-fraud purposes. MaxMind states that they 'employ user-entered location data from sites that ask web visitors to provide their geographical location…. and run them through a series of algorithms that identify, extract and extrapolate location points for IP addresses.'

I wanted to know how it can be possible to find out one's geographical location just from their IP address. The head of a UK Internet Service Provider explained to me that location information cannot be derived directly from a user's IP. For example, my own IP address is registered via RIPE (a Regional Internet Registry, see **www.ripe.net**), and only my ISP (acting as an LIR or Local Internet Registry in all this) knows my precise location. RIPE only knows that my IP is allocated to a UK user, nothing else. So where can more precise Geographical IP location data come from?

RIPE is one of the registries responsible for the allocation of IP addresses: they only know the country code, not the end-user's physical location

To test this further, we tried the ADSL address of an IP CCTV camera to see what would happen. The key point is that no form of surfing or web browser was going on at that dedicated IP address, and the IP address had not been used by anyone else, so it was considered 'clean'. The GeoIP lookup came back as IP 1XX.XX.[REDACTED] GB United Kingdom H9 London, City of London 51.5002 -0.1262 … That is about as wide of the mark as it is possible to be, because the CCTV camera is located 450 miles away in Scotland.

My own IP address was then tested, and a reasonably close approximation of my address was displayed. This again begs the question of user privacy, as it is being claimed that private data from, for example, web browsing or form-filling – excluding the user's name – is being captured and exchanged by certain websites. This seems to be the only way in which a physical location can be gleaned from a user's IP, given that not even RIPE (in my case) knows my geographical address, and it's RIPE that allocated the IP address to my broadband provider to begin with. And what if a user changes IP address? Can the location of another user be wrongly paired with a recycled IP address? Many questions are thrown up by this practice, which will doubtless come under more scrutiny over time.

That's all for this month's *Net Work*. You can email me at **alan@epemag.demon.co.uk** or write to the editor for possible publication in *Readout* at **editorial@wimborne.co.uk**
There is also a new section dedicated to *Net Work* in our forum at **www.chatzones.co.uk**

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COMPUTING AND ROBOTICS

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N. Kantaris and P. R. M. Oliver

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Covers the Vision command system

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R.A Penfold

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There are now numerous accessories that are relatively inexpensive and freely available, for those wishing to customise their PC with added colour and light. Cables and fans can be made to glow, interior lights can be added, and it can all be seen to good effect through the transparent case. Exterior lighting and many other attractive accessories may also be fitted.

This, in essence, is case modding or PC Customising as it is sometimes called and this book provides all the practical details you need for using the main types of case modding components including:- Electro luminescent (EL) 'go-faster' stripes: Internal lighting units: Fancy EL panels: Data cables with built-in lighting: Data cables that glow with the aid of 'black' light from an ultraviolet (UV) tube: Digital display panels: LED case and heatsink fans: Coloured power supply covers.

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COMPUTING & PROJECT BUILDING

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R. A. Penfold

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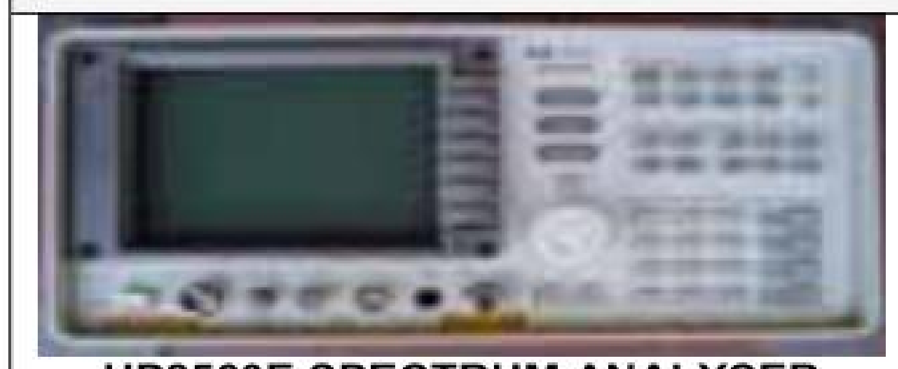

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